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University of Illinois at Urbana-Champaign

College of Agriculture Cooperative Extension Service

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Agricultural Research and
Demonstration Centers

Cover photo: aerial view of the Brownstown Agronomy Research Center in Fayette County. The Brownstown Center is one of eight University of Illinois agricultural research and demonstration centers that have a major agronomic component.

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Yield Goals

Management decisions are made more easily if the corn producer has set realistic yield goals based on his soil, climate, and available equipment. It usually is not realistic, for example, to set yield goals of 180 bushels per acre for a soil rated to produce only 100 bushels per acre, and where the highest yield ever produced was 130 bushels per acre. Instead, managing to achieve a realistic yield goal should result in yields greater than the goal in years when conditions are better than average, and reduced losses when the weather is unfavorable. This should be considered an *average* yield goal; it will not guarantee high yields when the weather is poor.

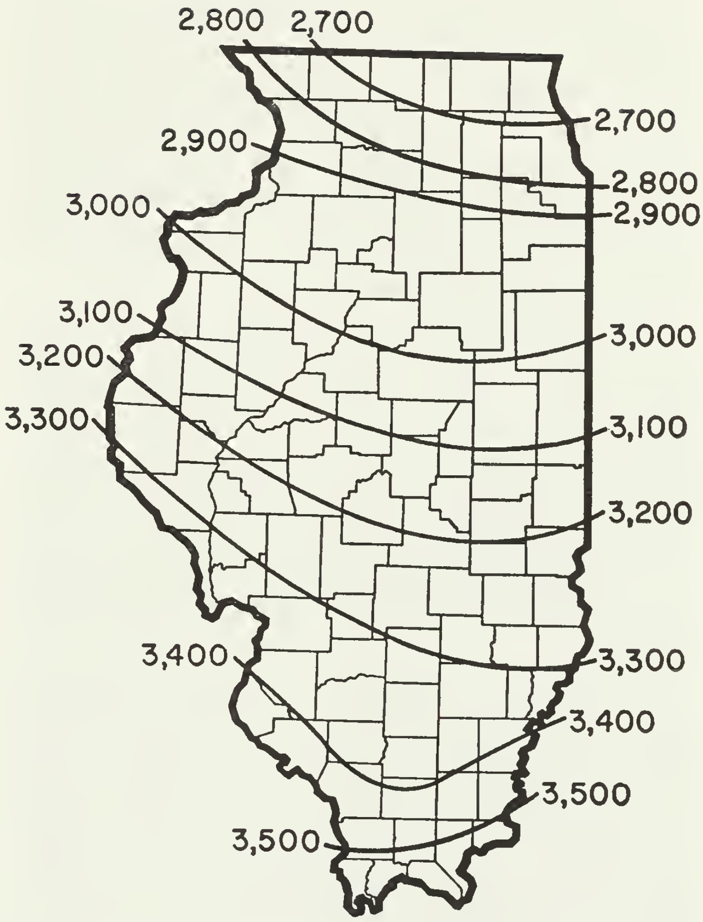
The first step in establishing a yield goal is a thorough examination of the soil type. Information for each soil type, such as the corn productivity ratings given in *Soils of Illinois* (Bulletin 778), can be a useful guideline. However, this information should be supplemented by 3- to 5-year yield records, county average yields, and the yields on neighboring farms. An attempt should be made to ignore short-term weather and to set a goal based on long-term temperature and rainfall patterns.

Hybrid Selection

When tested under uniform conditions, the range in yield of available hybrids is often 30 to 50 bushels per acre. This means that the time spent in choosing a hybrid can be some of the most productive time the producer spends. Maturity, yield for that maturity, standability, and disease resistance are the most important factors to consider when making this choice.

There is some concern with what many consider to be a lack of genetic diversity among commercially available hybrids. While it is true that a limited number of genetic pools, or populations, were used to produce today's hybrids, it is important to realize that these pools contain a tremendous amount of genetic diversity. Even after many years of breeding, there is no evidence that this diversity has been fully exploited. In fact, a number of studies have shown that breeding progress is not slowed, even after a large number of cycles of selection. Continued improvements in most desirable traits are evidence that this is true. Many of today's hybrids are substantially better than those that are only a few years old. This is the reason that some producers feel that a hybrid "plays out" within a few years. Actually, the performance of a given hybrid remains constant over years, but comparison with newer and better hybrids may make it appear to have declined in yielding ability.

Maturity is one of the important characteristics used in choosing a hybrid. Hybrids that use most of the growing season to mature generally produce higher yields than those that mature more quickly. The latest-maturing hybrid should reach maturity at least two weeks before the average date of the first killing freeze (32°F),



Average number of growing degree days, May 1 through September 30, based on temperature data provided by the U.S. Department of Commerce, National Weather Service, 1951-1980. (Fig. 1)

which occurs about October 8 in northern Illinois, October 18 in central Illinois, and October 25 in southern Illinois. Physiological maturity is reached when kernel moisture is 30 to 35 percent, and is easily identified by the appearance of a black layer on the base of the kernel where it attaches to the cob. The approach to maturity can also be monitored by checking the "milk line," which moves from the crown to the base of the kernel as starch is deposited. The kernel is mature at about the time this milk line disappears at the base of the kernel.

While full-season hybrids generally produce highest yields, most producers choose hybrids of several different maturities. This practice allows harvest to start earlier and also reduces the risk of stress damage by lengthening the pollination period. Growing hybrids of different maturities also assures some genetic diversity.

Comparing hybrid maturities can be difficult, since there is no uniform way of describing this characteristic. Some companies use days to maturity, while others use growing degree days (GDD). Growing degree days is becoming more widely used, and it is usually possible

to obtain this measure for any hybrid, either directly or by comparison of maturity with a hybrid for which GDD is known.

To match a hybrid to his growing season, a producer should determine what the average GDD total is for his area (Fig. 1). GDD is calculated on a daily basis as the average temperature (minimum plus maximum divided by 2) minus 50°F, then 50°F is substituted, and if the maximum is greater than 86°F, then 86°F is substituted for the actual temperature. Using this system, corn should be mature when the total GDD accumulation after planting equals the number of GDD specified by the seed company as necessary to reach maturity.

A full-season hybrid for a particular area will generally mature in several hundred fewer GDD than that given in Figure 1. Thus, a full-season hybrid for northern Illinois would be one that matures in about 2,500 GDD, while for southern Illinois a hybrid that matures in 2,900-3,000 GDD would be considered full season. This GDD "cushion" reduces the risk of frost damage and also allows some flexibility in planting time; it may not be necessary to replace a full-season hybrid with one maturing in fewer GDD unless planting is delayed until late May.

After yield and maturity, resistance to lodging is probably the most important factor in choosing a hybrid. Because large ears tend to draw nutrients from the stalk, some of the highest-yielding hybrids also have a tendency to lodge. Such hybrids may be profitable because of their high yields, but they should be closely watched as they reach maturity. If lodging begins, or if stalks become soft and weak (as determined by pinching or pushing on stalks), then harvest of these fields should begin early.

Resistance to diseases and insects are important characteristics in a corn hybrid. Leaf diseases are easiest to spot, but stalks should also be checked for diseases. Resistance to insects, such as the European corn borer, is also being incorporated into modern hybrids. Another useful trait is the ability of the hybrid to emerge under cool soil conditions. This is especially important in reduced or zero-till planting.

With the large number of hybrids being sold, it is difficult to choose the best one. An important source of information on hybrid performance is the Illinois Cooperative Extension Circular, *Performance of Commercial Corn Hybrids in Illinois.* This is the summary of hybrid tests run each year in ten locations, and includes information from the previous two years. The circular gives data on yields, kernel moisture, and lodging of hybrids. Other sources of information include your own tests and tests conducted by seed companies, neighbors, and county extension personnel.

You should see the results of as many tests as possible before choosing a hybrid. Good performance for more than one year is one important criterion. You should not base your decision on the results of only one "strip test." These tests use only one strip of each hybrid; the difference between two hybrids may therefore be due to location in the field rather than to an actual superiority of one over the other.

Planting Date

Long-term studies in Illinois show that corn planted by May 1 in southern Illinois and by May 10-15 in northern Illinois normally produces higher yields than corn planted later. It is therefore good to have all or most of the corn planted by May 1 in southern Illinois and by May 10 or 12 in northern Illinois. Weather and soil conditions permitting, you should begin planting sometime before those dates to allow for bad working days (Table 1). Corn that is planted 10 days or 2 weeks before the optimum date may not yield as much as that planted on or near the optimum date, but it will usually yield considerably more than that planted 2 weeks or more after the optimum date (Table 2). Early planting also results in drier corn in the fall, allows for more control over the planting date, and allows for a greater choice of maturity in hybrids. In addition, if the first crop is damaged, the decision to replant can often be made early enough to allow you to use your first-choice hybrid.

Of course, early planting has some disadvantages: (1) the cold, wet soil may produce a poor stand, (2) weed control may be more difficult, and (3) plants may suffer from frost. However, improved seed treatments and herbicides have greatly reduced the first two hazards, and the fact that the growing point of the corn plant remains below the soil surface for 2 to 3 weeks after emergence minimizes the third hazard. Since it is below the surface, this part of the plant is seldom dam-

Table 1. — Days Available and Percent of Calendar Days Available for Field Operations in Illinois[a]

Period	Northern Illinois		Central Illinois		Southern Illinois	
	Days	Pct.	Days	Pct.	Days	Pct.
April 1-20[b]	5.8	(29)	4.2	(21)	2.6	(13)
April 21-30[c]	3.5	(35)	3.1	(31)	2.6	(26)
May 1-10[c]	5.8	(58)	4.3	(43)	3.5	(35)
May 11-20[c]	5.5	(55)	5.0	(50)	4.4	(44)
May 21-30[c]	7.4	(74)	5.8	(58)	5.4	(54)
May 31-June 9[c]	6.0	(60)	5.4	(54)	5.6	(56)
June 10-19[c]	6.0	(60)	5.4	(54)	5.8	(58)

[a] Summary prepared by R. A. Hinton, Department of Agricultural Economics of the University of Illinois Cooperative Crop Reporting Service, unpublished official estimates of Favorable Work Day, 1955-1975. The summary is the mean of favorable days omitting Sundays, less one standard error, representing the days available 5 years out of 6.
[b] 20 days.
[c] 10 days.

Table 2. — Effect of Planting Date on Yield[a]

	Northern Illinois	Central Illinois	Southern Illinois
Late April	...	156	102
Early May	151	162	105
Mid May	150	...	82
Early June	100	133	58

[a] 3-year average at each location.

aged by cold weather unless temperatures drop low enough and stay low long enough to freeze the soil. Even when corn is frosted, therefore, the probability of regrowth is excellent. For these reasons, the advantages of early planting are felt to outweigh the disadvantages.

The lowest temperature at which corn will germinate is about 50° F. Therefore, planting may begin when the soil temperature at planting depth is 50° F. or higher. The five-day weather forecast also should be favorable. You probably will need to determine soil temperature on your own because soil temperatures reported by weather bureaus usually are taken under sod. The mid-day temperature at 2 to 4 inches under sod often is 8 to 12 degrees lower than it is under bare ground.

The following guides may be helpful:

1. Plant when the temperature at 7 a.m. reaches 50° F. at the 2-inch level. This will assure a favorable temperature for growth during most of a 24-hour period if there is an appreciable amount of sunshine.

2. Plant when the temperature at 1 p.m. reaches 55° F. at the 4-inch level. The 4-inch level is suggested for the 1 p.m. measurement because this level is not affected as much as the 2-inch level by a single day of bright sunshine.

After May 1, plant if the soil is dry enough even if the soil temperature is below the suggested guidelines. Perhaps a simple way to say it is plant according to soil temperature early in the season, later on plant by the calendar.

Some areas, such as river bottoms and low-lying flatlands, tend to warm up slowly and are subject to late freezes. These areas should be the last to be planted.

When planting in April, plant the full-season hybrids first and be sure of your weed control program. You also may consider increasing your planting rate 1,000 to 2,000 kernels per acre because the early planted corn is normally shorter and is less likely to be under moisture stress when pollinating.

Planting Depth

Ideal planting depth varies with soil and weather conditions. Emergence will be more rapid from relatively shallow-planted corn; therefore, early planting should not be as deep as later planting. An ideal depth for normal conditions is about 2 inches. Early planted corn should not be any deeper than that; up to ½ inch shallower is preferred. Later in the season when temperatures are higher and evaporation is greater, planting 1 inch deeper to reach moist soil may be advantageous.

Depth-of-planting studies show that not only do fewer plants emerge when planted deep, but also that those that do emerge often take longer to reach the pollinating stage and may have higher moisture in the fall.

Plant Population

Your goal at planting time is the highest population per acre that can be supported with normal rainfall without excessive lodging, barren plants, or pollination problems. How do you know when you have found the ideal

Table 3. — Effect of Population on Corn Yield, Urbana

Variety	Plants per acre planted in 30-inch rows		
	16,000	24,000	32,000
		Bushels per acre	
A	127	140	153
B	126	98	62

Table 4. — Effect of Row Width on Corn Yield, Urbana

Plants per acre	Row width	
	40 inches	30 inches
	Bushels per acre	
16,000	127	132
24,000	133	144
32,000	126	138

or optimum population for a particular field? Check the field for average ear weight. You can check at maturity or estimate by counting kernels (number of rows × number of kernels per row) once the kernel number is set. A half-pound ear will have an average of 640 kernels. Most studies in Illinois show that there is a very close relationship between half-pound ears and optimum population. A half-pound ear should shell out 0.4 of a pound of grain at 15.5 percent moisture. The optimum population for a particular field is influenced by several factors, some of which you can control and some over which you have little or no control. Concentrate on those factors that you can control. For instance, there is little that you can do to affect the amount of water available to the crop during the growing season. This variable is determined by the soil type and the total amount and distribution of the rainfall between the time the crop is planted and when it is mature. But there is much that you can do about how efficiently this water is used. The more efficient its use, the higher the population that can be supported with the water that is available. Remember that ear number is generally more important than ear size, and that the most practical way to increase ear number with today's hybrids is through population control.

Two very important factors influencing the efficiency of water use that you can control are soil fertility and weeds. Keep the fertility level of your soil high and the weed population low.

Other factors that are important include:

1. Hybrid selection. Hybrids differ in their tolerance to the stress of high populations (Table 3). Most modern hybrids can, however, tolerate populations of 20 to 24 thousand per acre under reasonably good conditions. Some need even higher populations — 25 to 28 thousand per year — to produce best yields.

2. Planting date. Early planting enables the plant to produce more of its vegetative growth during the long days of summer and to finish pollinating before the normal hot, dry weather in late July and early August.

3. Row width (Table 4).

4. Insect and disease control.

Table 5. — Planting Rate That Allows for a 15 Percent Loss From Planting to Harvest

Plants per acre at harvest	Seeds per acre at planting time
16,000	18,800
18,000	21,200
20,000	23,500
22,000	25,900
24,000	28,200
26,000	30,600
28,000	33,000
30,000	35,300

The harvest population is always less than the number of seeds planted. Insects, diseases, adverse soil conditions, and other hazards take their toll. You can expect from 10 to 20 percent less plants at harvest than seeds planted (Table 5).

Specialty Types of Corn

White corn. Most of the white corn grown in the United States is used to make corn flakes and cornmeal. It often sells at a higher price than yellow corn, sometimes as much as 1½ to 2 times the price of yellow corn.

The cultural practices for producing white corn are the same as those for yellow corn except that there are relatively few white hybrids available in maturities adapted to Illinois. Choice of hybrid is therefore important. In addition, kernels developed from ovaries pollinated by pollen from yellow hybrids will be light yellow. These yellowish kernels are undesirable. The official standards for corn specify that white corn not contain more than 2 percent of corn of other colors. Therefore, white corn probably should not be planted on land that produced yellow corn the year before. It also may be desirable to harvest the outside ten or twelve rows separate from the rest of the field. Most of the pollen from adjacent yellow corn will be trapped in those outer rows.

High-lysine corn. Lysine is one of the amino acids essential to animal life. Livestock producers need not be concerned whether the protein that ruminant animals eat contains this amino acid because the microflora in rumen can synthesize lysine from lysine-deficient protein. Nonruminants cannot do this, however, so swine, poultry, and humans must have a source of protein that contains sufficient lysine to meet their needs.

Normal dent corn is deficient in lysine. The discovery in 1964 that the level of this essential amino acid was controlled genetically and could be increased by incorporating a gene called Opaque 2 was exciting news to the corn geneticist and the animal nutritionist.

The potential value of this discovery to the swine farmer was obvious when feeding trials demonstrated that substantially less soybean meal was required when high lysine corn was fed to swine.

Agronomic research with high-lysine corn indicates that it is slightly lower in yield and higher in moisture than its normal counterpart. Furthermore, the kernel is softer and more susceptible to damage. Current research with more sophisticated hybrids, however, indicates that these differences in yield and kernel characteristics may be overcome.

The Opaque 2 gene is recessive: high-lysine corn pollinated by normal pollen produces normal low-lysine grain. Although isolation from normal corn is not essential, regular hybrids, for example, should not be strip planted in high-lysine corn, nor should high-lysine be planted where volunteer normal corn will be high.

Popcorn. As with several of the other specialty types of corn discussed earlier, most of the popcorn produced in Illinois is under contract to processors. While there are several dozen hybrids to choose from, the processor may require that a hybrid be grown for its particular kernel characteristics rather than for yield alone. Thus, income per acre should be considered, since low-yielding hybrids may often bring a higher price.

Cultural practices for popcorn are much like those for field corn. Popcorn often is attacked by stalk rot, so excessively high plant populations should be avoided, and harvest should begin as soon as the grain is dry enough. Weed control may also be more difficult because of slower emergence and early growth. Rotary hoeing and cultivation may be useful supplements to chemical weed control. Since popcorn yields 30 to 40 percent less than field corn, fertilizer needs should generally be somewhat lower.

Many newer popcorn hybrids are "dent sterile," meaning that field corn pollen cannot fertilize popcorn kernels. This should reduce the need for isolation, but be sure to check with the contractor about this. It is generally best to avoid planting popcorn in a field where field corn grew the previous season.

High-oil corn. In the summer of 1896, Dr. C. G. Hopkins of the University of Illinois started breeding corn for high oil content. With the exception of three years during World War II, this research has continued. The oil content of the material that has been under continuous selection has been increased to 17.5 percent from the 4 to 5 percent that is normal for dent corn.

Until recently, yields were disappointing for varieties with higher oil content than normal dent corn. However, recent research involving new gene pools of high-oil material unrelated to the original Illinois High Oil indicates that varieties containing 7 to 8 percent oil may be produced with little or no sacrifice in yield. Experimental higher oil hybrids will probably be marketed soon on a limited scale.

Since oil is higher in energy per pound than starch, a livestock ration containing high-oil corn should have some advantage over one containing normal corn. Feeding trials involving high-oil corn have generally confirmed this assumption. The corn-milling industry's interest in high-oil corn as a source of edible oil is in-

creasing. Corn oil has a high ratio of polyunsaturated fatty acids to saturated fatty acids. It is used in salad oils, margarine, and cooking oils.

Waxy maize. Waxy maize is a type of corn that contains 100 percent amylopectin starch instead of the 75 percent typical for ordinary dent hybrids. Amylopectin starch is used in many food and industrial products.

Our chief source of amylopectin starch prior to World War II was tapioca imported from eastern Asia. The Japanese occupation of what was then the Dutch East Indies essentially cut off our supply of tapioca. An emergency program to develop and produce waxy maize was undertaken by the government. After the war, waxy maize continued to be an important supply of amylopectin starch. Several corn-milling companies annually contracted for its production in the central Corn Belt.

The waxy characteristic is controlled by a recessive gene. Therefore, waxy corn pollinated by pollen from normal corn will develop into normal dent corn. Waxy corn, like high-lysine corn, should not be planted in fields where dent corn is likely to volunteer. The outside six to ten rows also may need to be kept segregated from the rest of the field to keep the amount of contamination from normal corn to an acceptable level.

High-amylose corn. High-amylose corn is corn in which the amylose starch content has been increased to more than 50 percent. Normal corn contains 25 percent amylose starch and 75 percent amylopectin starch.

The amylose starch content also is controlled by a recessive gene. Therefore, isloation of production fields is important, as is selecting production fields that were not in normal corn the previous year.

SOYBEANS

Planting Date

Soybeans should be planted in May. The full-season varieties will yield best when planted in early May. Earlier varieties often yield more when planted in late May than in early May. The loss in yield of the full-season varieties when planting is delayed until late May is minor compared with the penalty for planting corn late. Therefore, the practice of planting soybeans after the corn acreage has been planted is accepted and wise.

The loss in yield of soybeans becomes more severe when planting is delayed past early June. However, the penalty for late-planted corn is proportionally greater and the danger of wet or soft corn becomes such a threat that soybeans are, under many conditions, a better crop for late planting than corn (Tables 6 and 7).

Table 6. — Yields of Soybeans Planted on Four Dates, Urbana

Variety	Date of planting			
	May 7	May 21	June 8	June 19
	Bushels per acre			
Corsoy	56	62	49	42
Beeson	57	55	52	47
Calland	56	51	47	40

Table 7. — Yields of Soybeans Planted on Four Dates, Carbondale

Variety	Date of planting			
	May 3	May 17	June 7	July 1
	Bushels per acre			
Corsoy	27	38	43	28
Cutler	62	46	54	27
Dare	72	45	37	32

Table 8. — Days to Maturity for Three Planting Dates, Columbia, Missouri (Six-Year Average)

Variety	Date of planting		
	May 1	June 1	June 12
	Days to maturity		
Hawkeye	122	104	98
Clark	149	115	105

Table 9. — Days to Maturity for Four Planting Dates, Carbondale

Variety	Date of planting			
	May 3	May 17	June 7	July 1
	Days to maturity			
Corsoy	118	103	107	101
Wayne	131	117	117	105
Cutler	145	133	117	108
Dare	159	153	138	122

Effect on maturity. The vegetative stage (planting to the beginning of flowering) is 45 to 60 days for full-season varieties planted at the normal time. This period is shortened as planting is delayed and may be only 25 to 26 days when these varieties are planted in late June or early July.

Soybeans are photoperiod responsive and the length of the night or dark period is the main factor in determining when flowering begins. The vegetative period also is influenced by temperatures — high temperatures shorten and low temperatures lengthen it — but the main effect remains that of the length of the dark period.

The length of the flowering period and that of pod filling also are shortened as planting is delayed. However, the effect of planting time on these periods is minor compared to that on the vegetative period.

As the length of the vegetative period grows shorter, the number of days it takes soybean plants to mature becomes fewer (Tables 8 and 9).

Planting Rate

A planting rate that results in 10 to 12 plants per foot of row at harvest in 40-inch rows, 6 to 8 plants in 30-inch rows, 4 to 6 plants in 20-inch rows, or 3 to 4 plants in 10-inch rows will provide maximum yield for May and very early June planting. Higher populations usually result in excessive lodging. Smaller populations often yield less, and the plants branch more and pod lower. This contributes to greater harvesting loss.

Populations should be increased by 50 to 100 percent for late June or early July plantings.

Planting Depth

Emergence will be more rapid and stands will be more uniform if soybeans are planted only 1½ to 2 inches deep. Deeper planting often results in disappointing stands.

Varieties differ in their ability to emerge when planted more than 2 inches deep, as the following table shows. Therefore, special attention should be given to planting depth of these varieties.

	Planting depth (in.)	*Percent emergence*
Beeson	2	71
	4	39
Hawkeye	2	80
	4	60

Row Width

If weeds are controlled, soybeans often will yield more in narrow rows than in traditional row spacings of 30 or more inches. The yield advantage for narrow rows is usually greatest for earlier-maturing varieties, with full-season varieties showing smaller gains in yield as row spacing is reduced to less than 30 inches. A multiyear study illustrates that average gains for narrow versus wider row spacings will vary from year to year (Table 10).

The following rule of thumb will predict situations in which narrower row spacings would be advantageous to yield. If a full canopy is not developed over the ground by the time that pod development begins, narrower spacings for soybeans can be advantageous to yield. Factors other than row spacing that influence canopy development by the time podding begins are: (1) maturity of the variety grown, (2) growing conditions during the vegetative period of plant development, and (3) planting date. Early-maturing varieties generally have the smallest canopies when podding begins. Dry or otherwise undesirable weather early in the season will reduce the amount of canopy grown prior to the onset of flowering by the soybean. Delays in planting reduce the amount of canopy that is developed before flowering.

Since late-planted soybeans normally are not as tall as those planted in early May, the advantage of using narrow rows increases as planting is delayed past early June. Double-crop soybeans planted after the small-grain harvest should be planted in rows at least as narrow as 20 inches (Table 11).

For many years some Illinois farmers have planted their soybeans with a grain drill. Interest in this planting method has increased to the point that in 1983 about 15 percent of the soybean acres in Illinois were planted in this way. The availability of improved herbicides has allowed the farmer to expand the use of this planting method. If weeds can be kept under control, the small grain drill is a practical narrow-row planting device for soybeans. Research does not always show an advantage for 7- or 8-inch rows over 15- or 20-inch spacings, but the drilled beans usually yield better than those planted in rows spaced 38 or 40 inches. A key factor to successful planting with a grain drill is maintenance of good weed control. Depth of planting also is more difficult to control with a grain drill. Because of these possible problems, farmers may wish to try this seeding method on a small acreage first.

For additional information on planting soybeans with a grain drill, see Illinois Cooperative Extension Service Circular 1161, *Narrow-Row Soybeans: What to Consider.*

Table 10. — Average Yield of 30 Soybean Lines in Wide and Narrow Row Spacings, 1980–1983

Year	Row spacings (inches) 30	15	10
	Bushels per acre		
1980	39.4	41.4	...
1981	55.8	...	61.6
1982	56.1	...	57.9
1983	53.5	...	54.4

When to Replant

Stand reductions of a uniform and irregular pattern have been evaluated for their effect on soybean yield potential (Tables 12 and 13). Studies strongly suggest that the soybean plant has a tremendous ability to compensate for missing plants. By developing more branches and podding more heavily, the effect of missing plants in the stand is often not detected in yields. Yield reduction suffered with very poor stands may still be more profitable to the grower than a replanted field which has additional costs associated with replanting and a reduced yield potential because of a delayed seeding date.

At a given level of stand reduction, the impact on yield is minimized if the gaps are small rather than large in size (Table 12). For instance, the two 40-inch gaps and the five 16-inch gaps both reduced the stand to 66 percent, but the treatment composed of more numerous small gaps was not as damaging to yield as the treatment with fewer but larger gaps. Other research done on this subject has suggested that a gap size of 16 inches has no effect at all on yield if rows adjacent to the gapped row have a full stand. Compensation for the single 16-inch gap has been found to occur not only in the row where the gap is located, but in the rows bordering the one containing the gap in the stand. Compensation demonstrated by soybeans (Tables 12 and 13) was measured in rows spaced at least 30 inches apart. Rows spaced more closely together should be able to compensate to even a greater degree.

Data presented in Table 13 illustrate the soybean's ability to compensate for missing plants when randomly placed gaps occur in the stand. With only 40 percent of the stand remaining, the production was 70 percent of the full stand. For the soybeans to exhibit their full capacity to compensate for missing plants, it is necessary

Table 11. — Yield of Double-Crop Soybeans When Planted in 20- and 30-Inch Rows in 1972

	20-inch rows	30-inch rows
	Bushels per acre	
Dixon Springs	53	43
Brownstown	37	32
Urbana	33	24

Table 12. — Soybean Compensation for Loss of Stand, Urbana, 1969

Treatment, 20-foot rows	Percent of full stand	Yield (bu/acre)
Six plants per foot of row	100	50
Three plants per foot of row	50	50
Five 9.6-inch gaps	80	47
Two 24-inch gaps	80	47
Five 16-inch gaps	66	47
Two 40-inch gaps	66	43
Five 24-inch gaps	50	44
Three 40-inch gaps	50	41

to control weed growth in the areas without plants. In a field situation where poor stands are realized, management to control weeds is essential to prevent further loss in yield potential because of poor stands.

Double Cropping

See Illinois Cooperative Extension Service Circular 1106, *Double Cropping in Illinois.*

Seed Source

In order to ensure a good crop, you must do a good job of selecting seed. When evaluating seed quality, consider the percent germination, percent pure seed, percent inert matter, percent weed seed, and the presence of diseased and damaged kernels.

Samples of soybean seed taken from the planter box as farmers were planting showed that homegrown seed was inferior to seed from other sources (Table 14). The number of seeds that germinate and the pure seed content of homegrown seeds were lower. Weed seed content, percent inert material (hulls, straw, dirt, and stones), and presence of other crop seeds (particularly corn) in homegrown seed were higher.

Farmers who purchased certified seed obtained a higher quality seed on the average than farmers purchasing uncertified seed.

This evidence indicates the Illinois farmer could improve the potential of his soybean production by using higher quality seed. Homegrown seed is the basic problem. Few farmers are equipped to carefully harvest, dry, store, and clean seeds, and to perform laboratory tests adequately to assure themselves of high-quality seed. Agriculture today is a professional enterprise. If a farmer is not a professional seed producer and processor, he may be well advised to market his soybeans and obtain high-quality seed from a reputable professional seedsman.

The state seed tag is attached to each legal sale from a seed dealer. Read the analysis and consider if the seed being purchased has the desired germination, purity of seed, and freedom from weeds, inert material, and other crop seeds. The certified tag verifies that an unbiased nonprofit organization (the Illinois Crop Improvement Association) has conducted inspections in the production field and in the processing plant. These inspections make certain the seeds are of a particular variety as named and have met certain minimum seed-quality standards. Some seedsmen may have higher quality seed than others. It pays to read the tag.

Table 13. — Soybean Yields from Random Irregular Stand Reductions, Champaign, 1982-1983*

	Percent stand remaining			
	100	80	60	40
Yield, bushels per acre	54	51	46	38
Yield, as percentage of a full stand	100	94	85	70

* Stand reductions done with random placed one-foot gaps sufficient to reduce stands to desired levels in rows spaced at 30 inches apart.

Table 14. — Quality Differences in Soybeans from Different Sources

	Germination	Pure seed	Weed seed	Inert matter	Other crops
			Percent		
Survey A					
Homegrown	79.6	95.5	0.02	2.29	2.27
Neighbor grown	80.8	97.5	0.01	2.06	0.41
Seed dealer	81.2	97.8	0.001	1.48	0.77
Survey B					
Uncertified	80.2	95.5	0.02	2.6	2.0
Certified	84.2	98.7	0.001	1.2	0.2

Varieties

Soybean varieties are divided into maturity groups according to their relative time of maturity (Table 15). Varieties of Maturity Group I are nearly full season in northern Illinois but are too early for good growth and yield farther south. In extreme southern Illinois the Maturity Group IV varieties range from early to midseason in maturity.

Following is a list of public soybean varieties that are available in Illinois. Varietal names marked with an asterisk (*) are protected varieties (see Plant Variety Protection Act, page 15).

Maturity Group I

Hardin* was developed and released by the Iowa State Agricultural Experiment Station in 1980. It matures about 3 days later than Hodgson 78, or 3 days earlier than Corsoy 79. It yields more than other varieties of similar maturity, has strong emergence tendencies, and is resistant to races 1 and 2 of Phytophthora root rot. It has the same lodging tendencies as Corsoy and Corsoy 79.

Hodgson 78* was developed by the University of Minnesota Agricultural Experiment Station. It was developed by backcrossing into the older Hodgson variety a genetic factor that carries resistance to races 1 and 2 of Phytophthora root rot. Hodgson 78 matures roughly 4 days earlier than Hark and is about 2 inches shorter.

Maturity Group II

Beeson 80* was released by Purdue University. It is an improved version of the original Beeson variety and is resistant to 7 different races of Phytophthora root rot. It matures about 3 days later than Amsoy 71. It is similar in size to Corsoy 79 and Amsoy 71, but it has greater lodging resistance.

BSR 201 was developed by Iowa State University. Its resistance to brown stem rot makes it particularly useful in fields infested with that pest. In the absence of brown stem rot, BSR 201 is quite competitive in yield

Table 15. — Characteristics and Parentage of Soybean Varieties

Maturity group and variety	Parentage and year released[a]	Flower color	Pubescence color	Pod color	Seed luster	Hilum color[b]
I						
Hardin	Corsoy^3 X Cutler 71 (1980)	purple	gray	brown	dull	yellow
Hodgson 78	Hodgson^7 X Merit (1978)	purple	gray	brown	dull	buff
II						
Beeson 80	Beeson^8 X Arksoy (1979)	purple	gray	brown	dull	imp. black
BSR 201	Pride B-216 X AX901-40-2 (1982)	white	gray	brown	dull	buff
Century	Calland X Bonus (1979)	purple	tawny	brown	dull	imp. black
CN 210	Beeson X L70-2283 (1983)	purple	gray	brown	shiny	buff
CN 290	Beeson X L70-2283 (1983)	purple	gray	brown	shiny	buff
Corsoy 79	Corsoy^6 X Lee 68 (1979)	purple	gray	brown	dull	yellow
Elgin	AP6 (2YT) (F_4) C1 (1983)	purple	tawny	brown	shiny	black
Gnome	Williams X Ransom (1979)	purple	tawny	tan	shiny	black
Wells II	Wells X Mack (1979)	purple	gray	brown	dull	imp. black
III						
Cumberland	Corsoy X Williams (1978)	purple	gray	brown	shiny	imp. black
Elf	Williams X Ransom dt_1 (1978)	purple	tawny	tan	shiny	black
Fayette	Williams^2 X PI88.788 (1981)	white	gray	tan	shiny	black
Harper	Unknown (1983)	purple	tawny	brown	shiny	black
Hobbit	Williams X Ransom (1981)	white	tawny	tan	shiny	black
Pella	L66L-137 X Calland (1979)	purple	tawny	tan	dull	black
Sprite	Williams X Ransom (1980)	white	tawny	tan	dull	black
Will	Williams^6 X (Clark^6 X T117) (1979)	white	tawny	tan	shiny	black
Williams 82	Williams^7 X Kingwa (1981)	white	tawny	tan	shiny	black
Woodworth	Wayne X L57-0034 (1975)	white	tawny	tan	dull	black
IV						
Bonus	C1266R X C1253 (1972)	purple	gray	brown	dull	imp. black
DeSoto	L66L-140 X Columbus (1979)	purple	tawny	brown	dull	black
Franklin	L12 X Custer (1978)	purple	gray	brown	dull	imp. black
Lawrence	Calland X Williams (1981)	purple	tawny	tan	dull	black
Pixie	Williams X Ransom (1980)	purple	tawny	tan	shiny	black
Union	Williams X SL11 (Wayne RpmRps) (1977)	white	tawny	tan	shiny	black
V						
Bedford	Forrest^3 X (D68-18 X PI88.788) (1978)	white	tawny	tan	shiny	black
Essex	Lee X 55-7075 (1973)	purple	gray	brown	....	buff
Forrest	Dyer X Bragg (1973)	white	tawny	....	shiny	black
Nathan	Forrest^2 X (D68-18 X PI88.788) (1980)	white	tawny	tan	shiny	black
Pershing	(Hill^2 X PI 171450) X Essex (1984)	white	gray	....	....	buff

[a] Superscript indicates the number of crosses in a backcrossing program.
[b] imp. = imperfect.

to the Century and Corsoy 79 varieties. Maturity of BSR 201 is similar to that of Amsoy 71. Resistance to races 1 and 2 of Phytophthora root rot and fair resistance to lodging are also found in BSR 201.

Century* was developed at Purdue University and was available to growers for the first time in 1981. It matures roughly 3 days later than Corsoy 79. Century is resistant to races 1 and 2 of Phytophthora root rot and has better lodging resistance than Beeson 80.

CN 210 was developed by the University of Illinois for use in fields infested with race 3 of the soybean cyst nematode. Maturity of CN 210 is 1 to 2 days before Corsoy 79, and it is resistant to Phytophthora root rot, races 1 and 2. In the absence of cyst nematodes, CN 210 will only yield about 90 percent as well as Corsoy 79, so use of the variety should be limited to fields with confirmed SCN infestations.

CN 290 was developed by the University of Illinois for use in fields infested with race 3 of the soybean cyst nematode. Maturity of CN 290 is similar to that of Beeson 80. Resistance to races 1 and 2 of Phytophthora root rot and to bacterial pustule is also found in CN 290. Yields of CN 290 are less than those from other varieties with similar maturity when the cyst nematode is absent. Therefore, the CN 290 should only be used in fields with confirmed SCN infestations.

Corsoy 79 is an improved version of Corsoy that was developed by the University of Illinois Agricultural Experiment Station. It is similar to the original Corsoy in emergence potential, maturity, and appearance, and like the older variety, it will show little lodging resistance in most years. It differs from the older Corsoy variety in that it has resistance to 7 races of Phytophthora root rot.

Elgin was developed by Iowa State University. Maturity of this variety is the same as that of Corsoy 79. Yield and lodging resistance of Elgin are generally better, however. Elgin lacks resistance to Phytophthora root rot, but has resistance to bacterial pustule.

Table 16. — Average Soybean Yields at Selected Locations in Illinois, 1982-84

Variety	DeKalb	Pontiac	Urbana	Girard	Belleville	Eldorado[b]
			Bushels per acre			
I						
Hardin[a]	54	32	51	..	..	..
II						
Beeson 80[a]	54	28	46	..	..	..
BSR 201	53	36	49	33	..	..
Century[a]	57	32	51	38	32	31
CN 210	46	31	..	..	..	..
CN 290	52	31	..	..	..	..
Corsoy 79	54	33	50	38	..	..
Elgin	58	31	53	37	..	..
Gnome[a]	55	37	52	33	..	..
Wells II[a]	53	30	49	..	..	..
III						
Cumberland[a]	..	37	53	40	41	42
Elf	..	41	55	..	..	40
Fayette	..	35	50	39	40	35
Harper	..	40	56	42	40	41
Hobbit[a]	..	37	54	42	32	41
Pella[a]	63	38	53	41	37	37
Sprite[a]	..	38	55	42	35	42
Will	..	36	50	..	..	..
Williams 82	..	38	53	39	45	39
IV						
Franklin	..	..	..	..	39	33
Lawrence	..	..	..	..	43	40
Pixie[a]	..	..	..	..	44	45
Union	..	..	..	..	40	40
V						
Essex	..	..	..	..	..	40
Pershing	..	..	..	..	..	47

[a] U.S. Protected Variety — see page 15. [b] 1982-83 data only.

Gnome* was developed by the Ohio Agriculture Experiment Station and was available to growers beginning in 1981. Its determinate growth habit makes the plant quite short and very resistant to lodging. It matures at about the same time as Beeson 80. Gnome performs best when grown in narrow rows and when given an abundance of fertilizer and water.

Wells II* was developed by Purdue University. It is similar in height to Corsoy 79 but matures roughly 2 days earlier and has much better lodging resistance. Whereas the original Wells has resistance to only races 1 and 2 of Phytophthora root rot, Wells II has resistance to 7 races.

Maturity Group III

Cumberland* was released by Iowa with Illinois participating. This new variety was selected from the cross of Corsoy and Williams. Maturity of Cumberland is about 2 days before Williams, but yields have been better than those of Williams. Plant size is similar to both Woodworth and Williams with lodging to a degree similar to Williams. It is susceptible to Phytophthora.

Elf is a short-statured determinate variety developed in Ohio from the crossing of Williams x Ransom. The short stature of Elf makes it very resistant to lodging, for the mature central stem length is usually 24 to 28 inches. Environments with high yield potential, where lodging may limit yield, are perhaps good places to use Elf. Maturity is 2 to 3 days later than that of Williams 82.

Fayette was developed by the University of Illinois and is unique in that it has resistance to races 3 and 4 of the soybean cyst nematode. It matures at the same time as Williams and Williams 82. The Fayette variety is susceptible to Phytophthora root rot and is only moderately resistant to lodging.

Harper was developed by Iowa State University and was released because it has a higher yield potential than varieties of similar maturity. It matures slightly later than Pella, making it an early Group III variety. Harper is reported to be moderately tolerant to Phytophthora root rot and resistant to bacterial pustule. Lodging resistance is very good.

Hobbit* was developed by Ohio State University. It was selected from the Williams x Ransom cross, as were Gnome, Sprite, Elf, and Pixie. Hobbit has excellent resistance to lodging and appears to have a yield advantage over Sprite. It matures about the same time as Woodworth.

Pella* was developed by the Iowa Agricultural Experiment Station and was available to growers beginning in 1981. It lodges less than Williams and is resistant to races 1 and 2 of Phytophthora root rot. Pella matures 3 days earlier than Cumberland.

Sprite* was developed by Ohio State University. It is a sister line to Gnome, Hobbit, Elf, and Pixie, all of which were selected from the Williams x Ransom cross. Sprite has excellent resistance to lodging and has a very good yield potential in high-yield environments. It has strong emergence but is susceptible to Phytophthora root rot. It matures about the same time as Woodworth.

Williams 82 is an improved form of the Williams variety that was released in 1972. The improvement is in Phytophthora root rot resistance. Williams 82 is resistant to at least 9 races of the pest. Plant size, maturity, and yield potential are essentially the same as that formerly found in Williams.

Woodworth is a selection from the same cross as Williams. It was released by the USDA and the University of Illinois in 1975. It is similar to Williams in height, lodging resistance, and seed quality but matures 3 to 4 days earlier. It is classed as susceptible to Phytophthora root rot but appears to have some tolerance to the disease. Woodworth is resistant to bacterial pustule and superior to Wayne and Calland in shattering resistance.

Maturity Group IV

Bonus* was developed by the USDA in cooperation with Purdue University. It matures about 2 days earlier than Cutler 71 and grows about 3 to 4 inches taller. The seed of Bonus is smaller than that of Cutler 71, and the quality (freedom from wrinkling, growth cracks, greenness, and moldy or rotten seeds) is better. Bonus is resistant to Phytophthora root rot but susceptible to frogeye leaf spot, bacterial pustule, and downy mildew. It tends to shatter more than Cutler 71. Bonus is similar to other varieties in oil content but is 1 to 2 percent higher in protein content.

DeSoto* was developed at Kansas State University. It matures about 3 days later than Union and has considerably better lodging resistance.

Franklin is an Illinois- and Missouri-developed variety released in 1978. Resistance to race 3 of the soybean cyst nematode and good yields are its outstanding features. Franklin is a fairly late-maturing Group IV variety. Lodging and seed shattering are not major problems.

Lawrence is a University of Illinois variety with a maturity similar to that of Union. The advantage Lawrence has over Union is improved resistance to lodging. Lawrence does not have resistance to Phytophthora root rot.

Pixie* was released by Ohio State University and was selected from the Williams x Ransom cross. Sister lines of Pixie are Gnome, Hobbit, Sprite, and Elf. Pixie matures about the same time as Union, but because of its determinate growth, it is much shorter and much more resistant to lodging. Very good yields have been obtained from Pixie and its other sister lines, but only under environments that are conducive to high yields. Pixie is susceptible to Phytophthora root rot.

Union has resistance to Phytophthora and downy mildew. It is also resistant to bacterial pustule. Union matures about 2 days earlier than Cutler 71. Union is comparable to Cutler 71 in plant height and lodging resistance. Seed quality is better than for Cutler 71 but not quite equal to that of Williams.

Maturity Group V

Bedford was jointly developed by Mississippi and Tennessee and released in 1978. The major advantage of Bedford is its resistance to races 3 and 4 of the soybean cyst nematode. Where race 4 of the cyst nematode is a problem Bedford will be useful by replacing Forrest which is susceptible to the pest. When race 4 is not a problem, Bedford and Forrest have similar yields. Heavy seeding rates for Bedford cannot be used because of severe lodging tendencies of the variety.

Essex was developed at the Virginia Agricultural Experiment Station. It is a very late variety (Group V) that has good resistance to lodging. It is resistant to bacterial pustule, several races of downy mildew, and frogeye leaf spot, and it has field tolerance to Phytophthora root rot. It is susceptible to the soybean cyst nematode.

Forrest* was developed at the Delta Branch Agricultural Experiment Station, Mississippi. It is a fairly late Group V variety. It is resistant to races 1 and 3 of the

Table 17. — Reactions of Soybean Varieties to Phytophthora Root Rot Disease

Maturity group	Susceptible to Phytophthora root rot	Resistant to races 1 and 2	Resistant to races 1, 2, and others
I		Hardin Hodgson 78	
II	Corsoy Elgin Gnome	BSR 201 Century CN 210 CN 290	Beeson 80 Corsoy 79 Wells II
III	Cumberland Elf Fayette Harper Hobbit Sprite Will Woodworth	Pella	Williams 82
IV	Crawford DeSoto Lawrence Pixie	Bonus Cutler 71 Franklin Union	
V	Bedford Essex Nathan Pershing	Forrest	

Table 18. — Soybean Variety Characteristics, 1982-84 Averages
(This information is of a general nature and should not be used for technical purity work)

Maturity group and variety	PV[a]	Relative maturity[b]	Lodging	Emergence	Height
I and II		Days	Score[c]	Score[d]	Inches
Hardin	X	−10	2.1	1	36
Wells II	X	− 9	1.3	4	37
CN 210[e]	..	− 8	1.9	..	37
Beeson 80	X	− 7	1.6	5	35
Corsoy 79	..	− 7	2.2	1	38
BSR 201	..	− 6	2.1	3	34
Elgin[e]	..	− 6	1.7	5	32
Century	X	− 4	1.6	4	35
CN 290[e]	..	− 3	1.8	..	36
Gnome	X	0	1.2	1	23
III					
Pella	X	0	1.5	3	38
Will	..	+ 2	1.4	..	35
Hobbit	X	+ 4	1.1	1	23
Cumberland	X	+ 5	1.7	3	37
Harper[e]	..	+ 5	1.4	5	35
Sprite	X	+ 6	1.2	1	24
Williams 82	..	+ 7	1.6	2	40
Fayette	..	+ 8	1.6	2	41
Elf	..	+ 9	1.1	1	24
IV and V					
Lawrence	..	+10	1.4	4	38
Pixie	X	+10	1.5	1	20
Union	..	+10	2.0	2	43
DeSoto	X	+11	2.0	4	41
Franklin	..	+12	2.0	3	44
Essex	..	+29	2.0	1	33
Pershing[e]	..	+29	1.3	..	30
Nathan	X	+35	3.5	1	48

[a] U.S. Protected Variety — see page 15.
[b] Relative to Pella.
[c] 1 = all plants standing, 5 = all plants flat
[d] 1 ≧ 85 percent emergence, 5 = 0-19 percent emergence, when seeds are planted 4½ inches deep in sand.
[e] Available to farmers in 1985.

soybean cyst nematode, bacterial pustule, wild fire, target spot, and Phytophthora root rot. It has excellent resistance to shattering.

Nathan* was developed and released by the Delta Branch Experiment Station, the West Tennessee Experiment Station, and the USDA. It matures about 5 days later than Essex but earlier than Bedford. Nathan is a tall plant with severe lodging tendencies. Its major advantage is its resistance to races 3 and 4 of the soybean cyst nematode. It lacks resistance to Phytophthora root rot.

Pershing is a University of Missouri release with a maturity similar to that of Essex. Advantages over Essex are in yield and lodging resistance. The relatively late maturity of Pershing will limit its use in Illinois to only the very southern portions of the state. SCN is frequently found in these areas, and it should be noted that Pershing is not resistant to this pest.

Private Varieties and Blends

Each year the University of Illinois conducts the Commercial Soybean Performance Test on many of the 400 different soybean varieties, blends, and brands now sold in Illinois. The results are published in an Extension Service circular and are available from all county Extension offices around January 1. The test report summarizes the yield, maturity, lodging resistance, height, and shattering resistance of the soybeans tested.

Blends of two or more varieties are usually identified by a brand name, such as "John Doe 200 Brand." Most blends are reconstituted with the same varieties in the same proportions each year; however, neither the Illinois Seed Law nor the Federal Seed Law requires this consistency.

A survey of soybeans that were available for planting in 1985 indicates that nearly 500 different varieties, blends, or brands will be marketed in Illinois.

PLANT VARIETY PROTECTION ACT

Congress passed the Plant Variety Protection Act in 1970. This law provides the inventor or owner of a new variety of certain seed-propagated crops the right to exclude others from selling, offering for sale, reproducing, exporting, or using the variety to produce a hybrid, different variety, or blend.

These rights are not automatic. The owner must apply for a certificate of protection. If the owner does not choose to protect the variety, it is public property and anyone may legally reproduce it and sell seed of it.

Essentially all varieties of the self-pollinated crops commonly grown in Illinois — such as soybeans and wheat — developed by private industry since 1970 are protected varieties. Many of the varieties developed at state experiment stations also are protected.

The law allows you, if you desire, to save your own production of a protected variety for seed. However, it does place certain restrictions on the sale of seed of a protected variety.

Under one provision of the act, the owner may stipulate that the variety be sold by variety name only as a class of certified seed. Seed of varieties protected under this provision of the act cannot be sold by variety name unless it is produced according to the standards and procedures of one of the official seed certification agencies in the United States. In Illinois, this is the Illinois Crop Improvement Association. The sale of uncertified seed of varieties protected in this manner also is a violation of the Federal Seed Act.

If the owner of a protected variety does not subscribe to the certified seed provision of the act, a farmer whose primary occupation is producing food or feed may sell seed of the protected variety to another farmer whose primary occupation is producing crops for food or feed. However, the second farmer may not sell as seed any of the crop that he produces.

Even if the protected variety is not covered by the certified seed provision of the act, anything advertising the sale of seed of that variety — including farm sale bills — usually is considered an infringement of the owner's rights. Therefore, any person desiring to sell seed of a protected variety must first obtain permission from the owner of the variety.

The container in which seed of a protected variety is sold should carry a label identifying the seed as that of a protected variety.

Both soft red and hard red winter wheat are grown in Illinois. Soft wheat is planted throughout Illinois, and many soft wheat varieties are sufficiently winter hardy to be grown anywhere in the state. Essentially all the hard wheat is grown in the northern half of Illinois, for two reasons. First, most of the popular hard varieties are more winter hardy than the soft varieties, and second, markets buying wheat in central and northern Illinois have traditionally preferred hard wheat. Most of this market preference has disappeared, and both types of wheat are now widely accepted commercially.

Wheat growers who are not presently growing soft wheat may be attracted by the yield, earlier maturity, and lodging resistance of some of the newer soft varieties. Producers in the northernmost counties who decide to grow soft wheat may also want to choose Argee for its excellent winter hardiness.

Date of Seeding

The Hessian-fly-safe dates for each county in Illinois are given in Table 19. Wheat planted on or after the fly-safe date is much less likely to be damaged by the insect than wheat planted earlier. It will also be less severely damaged in the fall by diseases such as Septoria leaf spot, which is favored by the rank fall growth usually associated with early planting. Since the aphids that carry the barley yellow dwarf (BYD) virus and the mites that carry the wheat streak mosaic virus are killed by freezing temperatures, the effects of these viruses will be less severe if wheat is planted shortly before the first killing freeze. Finally, wheat planted on or after the fly-safe date will probably suffer less from soil-borne mosaic; most of the soft red wheat varieties carry good resistance but may show symptoms if severely infested.

Rate of Seeding

Rate-of-seeding trials involving several different wheat varieties have been conducted in Illinois. The results of these trials indicate that 1½ bushels (90 pounds) of good seed per acre is adequate when planting at the normal time. The rate may be increased if seeding is delayed well past the fly-free date.

Seed Treatment

Treating wheat seeds with the proper fungicide or mixture of fungicides is a cheap way to help insure improved stands and better grain quality. In addition, the yield from treated seed usually will be higher than that from untreated seed.

The Department of Plant Pathology suggests several fungicides for treating seeds, including captan, maneb, HBC, thiram, and Vitavax. Vitavax controls loose smut in wheat and barley and should be used if this disease was present in the field where the seed was produced. Since Vitavax is not effective on some of the other seed-borne diseases that cause seedling blight (such as Septoria), another fungicide should be used along with Vitavax. Should you desire additional information concerning wheat diseases or seed treatment methods and materials, contact the University of Illinois Department of Plant Pathology or your county extension adviser.

Depth of Seeding

Wheat should not be planted more than 1 to 2 inches deep. Deeper planting may result in poor emergence. This

Table 19. — Average Date of Seeding Wheat for Highest Yield

County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield
Adams	Sept. 30-Oct. 3	Lee	Sept. 19-21
Alexander	Oct. 12	Livingston	Sept. 23-25
Bond	Oct. 7-9	Logan	Sept. 29-Oct. 3
Boone	Sept. 17-19	Macon	Oct. 1-3
Brown	Sept. 30-Oct. 2	Macoupin	Oct. 4-7
Bureau	Sept. 21-24	Madison	Oct. 7-9
Calhoun	Oct. 4-8	Marion	Oct. 8-10
Carroll	Sept. 19-21	Marshall-	
Cass	Sept. 30-Oct. 2	Putnam	Sept. 23-26
Champaign	Sept. 29-Oct. 2	Mason	Sept. 29-Oct. 1
Christian	Oct. 2-4	Massac	Oct. 11-12
Clark	Oct. 4-6	McDonough	Sept. 29-Oct. 1
Clay	Oct. 7-10	McHenry	Sept. 17-20
Clinton	Oct. 8-10	McLean	Sept. 27-Oct. 1
Coles	Oct. 3-5	Menard	Sept. 30-Oct. 2
Cook	Sept. 19-22	Mercer	Sept. 22-25
Crawford	Oct. 6-8	Monroe	Oct. 9-11
Cumberland	Oct. 4-5	Montgomery	Oct. 4-7
DeKalb	Sept. 19-21	Morgan	Oct. 2-4
DeWitt	Sept. 29-Oct. 1	Moultrie	Oct. 2-4
Douglas	Oct. 2-3	Ogle	Sept. 19-21
DuPage	Sept. 19-21	Peoria	Sept. 23-28
Edgar	Oct. 2-4	Perry	Oct. 10-11
Edwards	Oct. 9-10	Piatt	Sept. 29-Oct. 2
Effingham	Oct. 5-8	Pike	Oct. 2-4
Fayette	Oct. 4-8	Pope	Oct. 11-12
Ford	Sept. 23-29	Pulaski	Oct. 11-12
Franklin	Oct. 10-12	Randolph	Oct. 9-11
Fulton	Sept. 27-30	Richland	Oct. 8-10
Gallatin	Oct. 11-12	Rock Island	Sept. 20-22
Greene	Oct. 4-7	St. Clair	Oct. 9-11
Grundy	Sept. 22-24	Saline	Oct. 11-12
Hamilton	Oct. 10-11	Sangamon	Oct. 1-5
Hancock	Sept. 27-30	Schuyler	Sept. 29-Oct. 1
Hardin	Oct. 11-12	Scott	Oct. 2-4
Henderson	Sept. 23-28	Shelby	Oct. 3-5
Henry	Sept. 21-23	Stark	Sept. 23-25
Iroquois	Sept. 24-29	Stephenson	Sept. 17-20
Jackson	Oct. 11-12	Tazewell	Sept. 27-Oct. 1
Jasper	Oct. 6-8	Union	Oct. 11-12
Jefferson	Oct. 9-11	Vermilion	Sept. 28-Oct. 2
Jersey	Oct. 6-8	Wabash	Oct. 9-11
Jo Daviess	Sept. 17-20	Warren	Sept. 23-27
Johnson	Oct. 10-12	Washington	Oct. 9-11
Kane	Sept. 19-21	Wayne	Oct. 9-11
Kankakee	Sept. 22-25	White	Oct. 9-11
Kendall	Sept. 20-22	Whiteside	Sept. 20-22
Knox	Sept. 23-27	Will	Sept. 21-24
Lake	Sept. 17-20	Williamson	Oct. 11-12
LaSalle	Sept. 19-24	Winnebago	Sept. 17-20
Lawrence	Oct. 8-10	Woodford	Sept. 26-28

is particularly true of the semidwarf varieties because coleoptile length is positively correlated with plant height. Drilling is the best way to insure proper depth of placement. If seed is broadcast, the seeding rate should be increased to compensate for seed that is placed too deep or too shallow for good emergence.

Width of Row

Research on row width generally shows little advantage for planting wheat in rows narrower than 7 or 8 inches. Yield is usually reduced by wider rows.

Varieties

Following is a list of public wheat varieties that are available in Illinois. Varietal names marked with an asterisk (*) are protected varieties (see Plant Variety Protection Act, page 15). The state and year of release are given in parentheses just after the name.

Soft Red Winter Wheat

Abe* (Indiana, 1972) is a beardless, white-chaffed variety that is similar to Arthur in parentage, lodging resistance, maturity, and weight per bushel. Under some conditions it will be slightly shorter. Abe is resistant to the Hessian fly and the soil-borne mosaic virus. It is moderately susceptible to powdery mildew.

Argee* (Wisconsin, 1976) is a bearded, white-chaffed variety that is 2 to 4 inches taller than Abe, is less resistant to lodging, and matures 6 to 8 days later. It is very winter hardy and is resistant to leaf rust, stem rust, and loose smut.

Arthur (Indiana, 1967) is a beardless, white-chaffed variety that is relatively short and stiff strawed. It is moderately resistant to loose smut, stem rust, and the soil-borne mosaic virus. It is susceptible to the Hessian fly and moderately susceptible to powdery mildew.

Arthur 71* (Indiana, 1971) is similar to Arthur except that it is resistant to races A and B of the Hessian fly and is more resistant to leaf rust.

Auburn* (Indiana, 1981) is a beardless, white-chaffed, winter-hardy variety that grows about 2 inches shorter and matures about 3 days later than Arthur. Auburn has good lodging resistance. It is resistant to the Hessian fly, powdery mildew, Septoria leaf spot, leaf rust, and the soil-borne mosaic virus.

Beau* (Indiana, 1976) is a beardless, white-chaffed variety that is similar to Abe in maturity and height but more resistant to lodging. Beau is resistant to the Hessian fly and the soil-borne mosaic virus and has some resistance to Septoria leaf spot and powdery mildew.

Caldwell* (Indiana, 1981) is a beardless, white-chaffed variety that matures about the same time as Arthur and grows 1 to 2 inches shorter. It has good lodging resistance and is slightly less winter hardy than Arthur. Caldwell is moderately resistant to leaf rust, powdery mildew, and the barley yellow dwarf virus. It is resistant to stem rust, Septoria leaf spot, the Hessian fly, and the soil-borne mosaic virus.

Compton* (Indiana, 1984) is a beardless variety that has brown chaff at maturity. It is 2 days later than Caldwell and about the same height. It is resistant to the Hessian fly and the spindle streak virus, and is moderately resistant to soil-borne mosaic, barley yellow dwarf, leaf rust, and Septoria leaf spot.

Fillmore* (Indiana, 1982) is a beardless variety that matures 4 to 6 days later than Arthur and is about 2 inches shorter. It is moderately resistant to the soil-borne mosaic virus and is resistant to leaf rust, powdery mildew, and Septoria leaf spot. It is less winter hardy than Arthur but has the same winterhardiness as Caldwell.

Hart (Missouri and Pennsylvania, 1977) is a bearded, white-chaffed variety that matures 1 to 2 days later than Abe, grows to about the same height, and is slightly less resistant to lodging. It is not as winter hardy as Abe. It has some tolerance to Septoria leaf spot, loose smut, and the barley yellow dwarf virus. It is susceptible to the Hessian fly and to leaf rust.

Oasis* (Indiana, 1973) is a beardless, white-chaffed variety that matures 1 to 2 days later than Arthur, grows 1 to 2 inches taller, and is less resistant to lodging. Oasis has good resistance to loose smut, the Hessian fly, the soil-borne mosaic virus, and Septoria leaf spot. It is moderately susceptible to powdery mildew.

Pike* (Missouri, 1980) is a beardless variety that matures at about the same time as Hart. Although it grows 1 to 2 inches shorter than Hart, it is slightly more susceptible to lodging. Pike is moderately resistant to the Hessian fly and Septoria leaf spot but is susceptible to powdery mildew.

Roland (Illinois, 1977) is a beardless, white-chaffed variety that matures about 2 days later than Abe, grows 2 to 4 inches shorter, and is more resistant to lodging. Roland weighs 1 or 2 pounds less per bushel than Abe. It is moderately resistant to leaf rust, powdery mildew, Septoria leaf spot, and the barley yellow dwarf virus. It is susceptible to the Hessian fly.

Rosen (Arkansas, 1980) is a beardless, white-chaffed variety that matures about 2 days later than Abe, grows 2 to 4 inches shorter, and is more resistant to lodging. Rosen tends to weigh 1 to 2 pounds less per bushel than Abe or Arthur. It is moderately susceptible to leaf rust, powdery mildew, and Septoria leaf spot, and is susceptible to the Hessian fly. Rosen is not very winterhardy.

Roy* (North Carolina, 1980) is a beardless, white-chaffed variety that is similar to Roland in maturity and plant type. The test weight of Roy is somewhat low. It is susceptible to powdery mildew, and its winterhardiness is questionable.

Scotty* (Illinois, 1982) is a beardless variety that matures about 2 days later than Arthur, grows 1 to 2 inches shorter, and is more resistant to lodging. Scotty weighs about 1 pound less per bushel than Arthur. It is

Table 20. — Yield Record of Winter Wheat Varieties in University of Illinois Tests

Variety	Brownstown Research Center				Urbana Research Center				Northern Illinois Research Center			
	1984		1982–84		1984		1982–84		1984		1982–84[a]	
	Yield	Test weight	Yield	Test weight	Yield	Test weight	Yield	Test weight	Yield	Test weight	Yield	Test weight
	bu./A.	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*
SOFT WHEAT												
Abe	63	57	55	57	53	55	65	57	61	59	67	59
Argee	..	..	..	..	..	..	..	..	81	58	78	56
Arthur 71	60	56	53	57	49	54	63	56	64	55	67	57
Auburn	63	55	59	57	48	53	77	56	72	54	81	56
Beau	55	57	52	57	47	53	67	57	60	56	..	..
Caldwell	76	55	62	55	63	54	84	56	79	59	85	58
Compton	60	58	..	..	60	56	..	..	67	58	..	..
Fillmore	63	57	58	57	56	54	76	56	71	56	74	58
Hart	66	58	61	57	62	54	73	57	66	56	75	57
Pike	70	54	61	55	43	56	73	57	63	51	72	54
Roland	61	50	58	53	53	54	73	56	71	54	77	55
Rosen	56	55	59	55	53	53	74	55	71	56	80	57
Roy	68	49	65	52	52	51	74	51	53	52	67	53
Scotty	60	56	60	56	50	55	72	56	62	58	70	57
Tyler	73	53	68	53	71	52	78	54	57	51	67	53
HARD WHEAT												
Centurk 78	..	..	..	..	61	54	69	57	63	59	66	59
Newton	..	..	..	..	57	57	74	57	61	61	67	60
Siouxland	..	..	..	..	69	54	..	..	77	59	..	..

[a] 1982 test abandoned because of winter injury.

highly resistant to powdery mildew and the soil-borne mosaic virus and is moderately resistant to leaf rust and stem rust. It is susceptible to the Hessian fly.

Tyler (Virginia, 1980) is a beardless, white-chaffed variety that grows about 3 inches taller than Abe and matures 4 days later. It is resistant to powdery mildew and the soil-borne mosaic virus but is susceptible to leaf rust and the Hessian fly. It has a lower test weight than Abe.

Hard Red Winter Wheat

Centurk* (Nebraska, 1970) is a bearded, white-chaffed variety. It is resistant to stem rust and moderately resistant to leaf rust and the soil-borne mosaic virus, but it is susceptible to the Hessian fly.

Centurk 78* (Nebraska, 1978) is a variety selected out of Centurk and similar to Centurk in all agronomic characteristics except that it has a higher yield and is more resistant to the soil-borne mosaic virus.

Newton* (Kansas) is a bearded, white-chaffed variety that matures about 2 days earlier than Centurk, grows about 4 inches shorter, and has better lodging resistance. Newton is moderately resistant to leaf and stem rust and the soil-borne mosaic virus but is susceptible to the Hessian fly. It is less winter hardy than Centurk.

Siouxland* (Nebraska, 1984) is a bearded, white-chaffed variety. It is 3 inches taller than Centurk 78 and of similar maturity. It has resistance to leaf rust, Septoria, and mildew. Seed is not being produced in Illinois in 1985, but this variety may have potential where hard wheat is grown.

Hard Red Spring Wheat

Spring wheat is not well adapted to Illinois. Since it matures more than 2 weeks later than winter wheat, it is in the process of filling kernels during the hot weather typical of late June and the first half of July. Consequently, yields average only about 50 to 60 percent those of winter wheat.

With the exception of planting time, production practices for spring wheat are similar to those for winter wheat. Spring wheat should be planted in early spring, as soon as a seedbed can be prepared.

Era is an awned, midseason to late semidwarf with good lodging resistance. It is resistant to stem and leaf rust, and tolerant to Septoria, bunt, loose smut, and ergot. Test weight is high.

Olaf is an awned, semidwarf variety of medium maturity with good lodging resistance. It is resistant to stem and leaf rust, but susceptible to loose smut. Test weight is medium.

Table 20, continued

Variety	Orr Research Center		Dixon Springs Research Center	
	1984	1982–84	1984	1982–84
	Yield	Yield	Yield	Yield
	bu./A.	*bu./A.*	*bu./A.*	*bu./A.*
SOFT WHEAT				
Abe	60	58	59	42
Argee	..	..	..	..
Arthur 71	59	54	54	39
Auburn	62	61	70	57
Beau	66	64	63	44
Caldwell	65	73	66	50
Compton	58	..	..	..
Fillmore	60	68	65	44
Hart	62	63	58	44
Pike	59	70	64	47
Roland	54	61	60	49
Rosen	62	59	62	53
Roy	55	68	59	48
Scotty	60	65	67	55
Tyler	68	75	59	51
HARD WHEAT				
Centurk 78	47	53	..	..
Newton	50	47	..	..
Siouxland	67	..	..	..

Table 21. — Hard Red Spring Wheat Performance, DeKalb

Variety[a]	1984		1979–84	
	Yield	Test weight	Yield	Test weight
	bu./A.	*lb./bu.*	*bu./A.*	*lb./bu.*
Ellar	38	57	36	60
Eureka	36	56	35	58
Tioga	34	54	35	58
Olaf	33	54	34	57
Era	35	56	36	58
Fletcher	33	53	32	56

[a] Listed from earliest to latest.

TRITICALE

Triticale is a new crop resulting from the crossing of wheat and rye. The crop is still in the developmental stage. The varieties currently available are not well adapted to Illinois and are usually deficient in some characteristic such as winter hardiness, seed set, or seed quality. In addition, they are of feed quality only. They do not possess the milling and baking qualities needed for use in human food.

The potential exists, however, for plant breeders to correct these deficiencies. When this is done, the crop may be valuable for its high protein content and high protein quality.

A limited testing program at Urbana and in DeKalb County indicates that the crop is generally lower yielding than winter wheat and spring oats. Both spring and winter types of triticale are available.

OATS

Spring Oats

To obtain high yields of spring oats, plant the crop as soon as you can prepare a seedbed. If you are planting oats after corn, you will probably want to disk the stalks; plowing will produce the highest yields but is usually impractical. If you are planting oats after soybeans, disking is usually the only preparation you will need, and it may be unnecessary if the soybean residue is evenly distributed.

Before planting, treat the seed with a fungicide or a combination such as captan plus Vitavax. Several other fungicides and combinations can be used. For more information, see your local Extension agent or contact the Department of Plant Pathology, University of Illinois, Urbana, Illinois. Seed treatment protects the seed during the germination process from seed- and soil-borne fungi.

Oats may be broadcast and disked in but will yield 7 to 10 bushels more per acre if drilled. When drilling, plant at a rate of 2 to 2½ bushels per acre. If the oats are broadcast and disked in, increase the rate by ½ to 1 bushel per acre.

For suggestions on fertilizing oats, see the section on soil testing and fertility.

Varieties

Following is a list of public oat varieties that are available in Illinois. Variety names marked with an asterisk (*) are protected varieties (See Plant Variety Protection Act, page 13). The state and year of release are given in parentheses just after the name.

Benson* (Minnesota, 1978) is a white oat that matures 5 to 6 days later than Lang, grows 5 to 6 inches taller, and is not as resistant to lodging. Benson is resistant to smut and moderately resistant to crown rust. It is susceptible to the barley yellow dwarf virus.

Clintford (Indiana) is a variety whose grain is light brownish white (light yellowish white in some seasons), large, plump, and very high in test weight. Clintford has very short, stiff straw with large-diameter stems and a compact panicle that distinguishes it from other varieties grown in Illinois. It matures about 2 days later than Lang.

Dal* (Wisconsin, 1972) is similar to Froker in height and straw strength and matures at about the same time as Froker (or about 8 days later than Lang). Dal kernels, which have a whitish color, contain about 2.5 percent more protein than other commonly grown varieties. Dal is moderately resistant to rust and smut but is susceptible to the barley yellow dwarf virus.

Froker (Wisconsin, 1970) matures about a week later than Lang, grows several inches taller, and is less resistant to lodging. Froker is susceptible to leaf rust, smut, and the barley yellow dwarf virus.

Garland (Wisconsin, 1962) is a yellow oat that matures about 3 to 4 days later than Lang. It has good test weight and stands well. Garland is susceptible to smut, rust, and the barley yellow dwarf virus.

Holden (Wisconsin, 1967) is a yellow oat that matures 5 to 6 days later than Lang. It is susceptible to rust and the barley yellow dwarf virus but is resistant to smut.

Jaycee (Illinois, 1967) is an early-maturing variety with light brownish to yellowish white, fairly large, plump kernels. Jaycee has short straw and stands well until maturity; after maturity, it weakens rapidly and may lodge severely. It is tolerant to the barley yellow dwarf virus and is resistant to some races of leaf rust and stem rust and to the common races of smut.

Lang (Illinois, 1977) is a yellow oat that matures about 1 day later than Jaycee and is similar in height. Lang is resistant to the barley yellow dwarf virus but is susceptible to smut and the rusts. Since its beard is difficult to thresh, it often produces a slightly lower weight per bushel than Otee. Lang has good lodging resistance.

Larry (Illinois, 1981) is a yellow oat that is similar to Lang in maturity, is higher in test weight, has a more attractive kernel, and is equal or superior to Lang in lodging resistance. It is also superior to Lang in resistance to the barley yellow dwarf virus, but like Lang, it is susceptible to the newer races of rust and smut.

Marathon* (Wisconsin, 1979) has light tan kernels. Although it matures about 9 days later than Lang and grows 8 to 10 inches taller, it has good lodging resistance. It has fair crown rust and smut resistance but is very susceptible to the barley yellow dwarf virus.

Moore* (Minnesota, 1979) has white kernels, matures about 4 to 5 days later than Lang, and grows 6 to 7 inches taller. It is more susceptible to lodging than Lang and Marathon. Moore is resistant to smut, moderately resistant to crown rust, and susceptible to the barley yellow dwarf virus.

Noble* (Indiana, 1974) matures about 2 to 3 days later than Lang. It is resistant to the races of loose smut now prevalent in Illinois and is moderately resistant to the barley yellow dwarf virus. It has limited resistance to the rusts and is susceptible to current predominant races. It is resistant to lodging.

Ogle (Illinois, 1981) is a yellow oat that matures 3 to 4 days later than Lang, grows 3 to 4 inches taller, and is similar to Lang in bushel weight and lodging resistance. It is superior to Lang in resistance to the barley yellow dwarf virus but, like Lang, is susceptible to the newer races of rust and smut.

Otee (Illinois, 1973) has a white grain that is higher in protein content than the grain of other varieties currently grown in Illinois. Otee matures 1 day later than

Table 22. — Yields of Spring Oat Varieties in University of Illinois Tests

Variety	Northern Illinois Research Center				Urbana Research Center				Date headed
	1984		1979–84		1984		1979–84		
	Yield	Test weight	Yield	Test weight	Yield	Test weight	Yield	Test weight	
	bu./A.	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*June*
Centennial	...	...	...	...	54	24	82*	28	16
Jaycee	...	...	...	...	64	29	93	32	10
Lang	121	37	97	32	53	25	103	30	11
Larry	110	37	96	33	53	26	105	31	11
Noble	117	38	95	33	64	26	101	31	13
Ogle	113	35	102	31	80	29	119	31	14
Otee	108	38	85	33	60	32	98	33	12
Porter	...	...	...	...	88	29	105*	32	19
Preston	106	40	85*	36	67	29	91*	32	12

* Data given are averages of only two years (1983-84).

Lang and has short straw and good lodging resistance. It has moderate resistance to rust and good resistance to the barley yellow dwarf virus.

Wright* (Wisconsin, 1975) is a yellow oat that matures 5 to 6 days later than Lang, grows several inches taller, and is less lodging resistant. It is resistant to crown rust and moderately resistant to leaf rust and stem rust, but it is susceptible to smut. It has some tolerance to the barley yellow dwarf virus and Septoria leaf spot. Its protein content is average.

Winter Oats

Winter oats are not as winter hardy as wheat and are adapted to only the southern third or quarter of the state. U.S. Highway 50 is about the northern limit for winter oats. Since they are somewhat winter tender and are not attacked by Hessian fly, planting in early September is highly desirable. Experience has shown that oats planted before September 15 are more likely to survive the winter than those planted after September 15.

The same type of seedbed is needed for winter oats as for winter wheat. The fertility program should be similar to that for spring oats. Seeding rate is 2 to 3 bushels per acre when drilled.

Norline, Compact, and **Walken** are sufficiently winter hardy to survive most winters in the southern third of the state.

Norline was released by Purdue University in 1960. It tends to lodge more than Walken and Compact. Compact was released by the University of Kentucky in 1968. It is short and more lodging resistant than Norline. Walken was released by the University of Kentucky in 1970. It is more lodging resistant than Norline and Compact but grows a little taller than those varieties.

BARLEY

Both spring and winter barley can be grown in Illinois. Spring barley is best adapted to the northern quarter or third of the state, but it has been grown successfully as far south as Champaign County. Winter barley is best adapted to the southern half of the state.

Watch out for armyworms and chinch bugs. Both prefer barley to almost any other crop.

Spring Barley

Plant spring barley early — about the same time as spring oats. Drill 1½ to 2 bushels of seed per acre. To avoid excessive lodging, harvest the crop as soon as it is ripe. Fertility requirements for spring barley are essentially the same as for spring oats.

Varieties

All varieties included in Table 23 are approved for malting.

Since spring barley is not a large crop in Illinois, Illinois-grown seed is usually nonexistent. Therefore, farmers interested in growing spring barley will need to obtain seed from Wisconsin or Minnesota. Morex, Larker, Manker, Glenn, and Beacon are all grown in those states, Morex and Larker being the most popular varieties.

Larker (North Dakota, 1961) is a 6-row, semi-smooth-awn variety with a white aleurone. It is more susceptible to lodging than Morex but has a higher test weight.

Morex (Minnesota, 1978) has semismooth awns, a colorless aleurone, and a 6-row spike. Morex matures about 1 day earlier than Larker and grows to about the same height, but it is more resistant to lodging.

Winter Barley

Winter barley is not as winter hardy as the commonly grown varieties of winter wheat, and should be planted about the same time or slightly earlier than winter wheat. Sow with a drill and plant at the rate of 2 bushels of seed per acre.

The fertility requirements for winter barley are similar to those for winter wheat except that less nitrogen will be required. Most winter barley varieties are less resistant to lodging than winter wheat varieties. Winter barley cannot stand "wet feet"; therefore, it should not be planted on land that tends to be low and wet. The barley yellow dwarf virus is a serious threat to winter barley production.

Table 23. — Spring Barley Performance, DeKalb

Variety	1984 Yield	1984 Test weight	1979–84 Yield	1979–84 Test weight	Date headed
	bu./A.	*lb./bu.*	*bu./A.*	*lb./bu.*	*June*
Azure	44	41	47*	42	..
Glenn	60	41	55	43	9
Karl	45	43	55	44	11
Larker	51	45	45	45	10
Manker	56	43	52	45	9
Morex	54	43	54	44	9
Robust	64	45	56*	44	..

* Data are averages of only two years (1983-84).

Varieties

Following is a list of public winter barley varieties that are available in Illinois. Variety names marked with an asterisk (*) are protected (see Plant Variety Protection Act, page 15). The state and year of release are given in parentheses just after the name.

Barsoy (Kentucky) matures very early and yields well but is probably the least winter hardy of the varieties tested.

Harrison (Indiana, 1963) grows taller than most varieties but has good straw strength. It is not quite as winter hardy as Pike and Paoli and is susceptible to the barley yellow dwarf virus.

Maury (Virginia, 1977) matures 4 to 5 days later than Pike. It grows 3 to 5 inches taller but has better lodging resistance. Maury is tolerant to the barley yellow dwarf virus. Although it is not as winter hardy as Paoli, it should survive all but the most severe winters.

Monroe (Virginia, 1976) was selected from the same cross as Maury and carries the same tolerance to the barley yellow dwarf virus. Like Maury, Monroe is not as winter hardy as Paoli but should still survive all but the most severe winters. It matures 1 to 2 days later than Maury.

Paoli* (Indiana, 1971) matures 1 to 2 days later than Pike and is equal to Pike in winter hardiness. It is not quite as resistant to lodging.

Pike* (Indiana, 1975) matures as early as Barsoy and is more winter hardy.

Table 24. — Winter Barley Performance

Variety	Brownstown Research Center 1984 Yield	Brownstown 1984 Test weight	Brownstown 1979–84 Yield	Brownstown 1979–84 Test weight	Urbana Research Center 1984 Yield	Urbana 1984 Test weight	Urbana 1979–84 Yield	Urbana 1979–84 Test weight	Date headed
	bu./A.	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*bu./A.*	*lb./bu.*	*May*
Barsoy	71	48	70	46	42	47	77	48	15
Henry	76	46	..	..	67	44	..	..	20
Maury	86	45	72	43	83	45	86	44	19
Perry	65	47	..	..	80	46	..	..	20
Pike	75	46	68	44	85	47	83	45	15

GRAIN SORGHUM

While grain sorghum can be grown successfully throughout Illinois, its greatest potential is in the southern third of the state. It is adapted to almost all soils, from sand to heavy clay. Its greatest advantage over corn is tolerance of moisture extremes. Grain sorghum usually yields more than corn when moisture is in short supply, though it seldom yields as much as corn under optimum conditions.

Fertilization. Nutrient requirements for sorghum are similar to those of corn. Since the response to nitrogen has been erratic, maximum rate of nitrogen suggested is about 125 pounds. Sorghum is sensitive to salt, and seeds should not be placed in direct contact with starter fertilizer.

Planting. Sorghum should not be planted until soil temperature is 65°F. or above. In the southern half of the state mid-May is considered the starting date; late May to June 15 is the planting date in the northern half.

Sorghum emerges more slowly than corn and requires a relatively fine and firm seedbed. Planting depth should not exceed 1½ inches, and ¾ to 1 inch is considered best.

Population and row spacing. Row spacing experiments have shown that 20- to 30-inch rows produce far better than 40-inch rows. Aim for a plant stand of 50,000 to 100,000 plants per acre, with the lower populations on droughtier soils. Four to 6 plants per foot of row in 30-inch rows at harvest and 2 to 4 plants per foot in 20-inch rows are adequate. Plant 30 to 50 percent more seeds than the intended stand. Sorghum may also be drilled using 8 to 10 pounds of seed per acre.

Weed control. Since emergence of sorghum is slow, controlling weeds presents special problems. Suggestions for chemical control of weeds are given in the back of this handbook. As with corn, a rotary hoe is useful before weeds become permanently established.

Harvesting and storage. Timely harvest is important. Rainy weather after sorghum grain reaches physiological maturity may cause sprouting in the head or weathering (soft and mealy grain), or both. Harvest can begin when grain moisture is 20 percent or greater, if drying facilities are available. Sorghum dries very slowly in the field.

Marketing. Before planting, check on local markets. Because of limited acreage in Illinois, many elevators do not purchase grain sorghum.

Grazing. After harvest, sorghum stubble can be used for pasture. Livestock should not be allowed to graze for one week after frost, since the danger of prussic acid or hydrocyanic acid (HCN) poisoning is especially high. Newly frosted plants sometimes develop tillers high in prussic acid.

SUNFLOWERS

Two kinds of sunflowers are produced in Illinois, the oil-seed sunflower and the nonoil, or confectionary, sunflower. The oil-seed sunflower bears a relatively small seed with an oil content of 38 to 50 percent. The hull is thin and dark and adheres closely to the kernel. The oil is highly regarded as a salad oil and because of its high smoke point is unusually good for frying food and popping popcorn. The meal is used as a protein supplement in livestock rations; however, because sunflower meal is deficient in lysine, it cannot be used as the only source of protein in rations for nonruminant animals. The protein and crude fiber content vary with the method of processing. The confectionary (nonoil) sunflower bears a larger seed with a lower oil content. The hull is also lighter in color, is usually striped, and separates easily from the kernel. Confectionary sunflowers are used for human food and bird feed.

Planting. Sunflowers may be planted at the same time as corn. Because many of the hybrids offered for sale in Illinois reach physiological maturity (25 to 30 percent moisture) in 90 to 100 days, they can also follow small grain plantings as second crops. Since sunflowers do not host the soybean cyst nematode, they are a possible substitute for soybeans as a double crop.

Oil-seed sunflowers should be planted at a population rate that will establish 20 to 25 thousand plants per acre on soils with good water-holding capacity, and 16 to 20 thousand plants per acre on coarser-textured soils with relatively low water-holding capacity. Confectionary sunflowers should be planted at a lower population rate to insure larger seed size.

The recommended planting depth is 1½ to 2 inches, or about the same as that recommended for corn. Sunflowers perform best when planted in 20- or 30-inch rows, but planting in wider rows will also produce good yields.

Harvesting. Agronomists in North Dakota recommend harvesting after seed moisture has dropped to 18 or 20 percent. Losses are greatly reduced when sunflower attachments are used on the conventional combine head. These attachments are long pan-like guards extending from the cutter bar.

Problems. Because sunflowers are not commonly grown in Illinois, it is important to locate a market before planting a crop.

Feeding by birds can become a serious problem in any sunflower field and is most likely to occur near farmsteads and wooded areas. Insects and diseases can also damage sunflower crops. The severity of the damage will increase as the acreage of sunflowers increases in a community and will vary from season to season.

CROPS FOR LATE PLANTING

In most years, flooding or some other disaster makes replanting of corn and soybeans necessary somewhere in Illinois.

When this happens, the most common questions are (1) is it too late to replant with corn or soybeans? (2) if it is not too late, how early a variety should be used? and (3) if it is too late for corn or soybeans, is there any other crop that can be substituted for feed-grain or cash-grain production?

Any answer to these questions assumes that (1) weather conditions following replanting will favor immediate germination and emergence, (2) rainfall and temperatures will favor normal growth and development, and (3) the first killing frost in the fall will be as late or later than average.

The following are estimates of how late corn and soybeans may be planted in Illinois.

In the northwestern corner of the state, where the first killing frost can be expected before October 5, June 15 is the latest date that early varieties of corn can be planted with reasonable assurance that they will be mature (30 to 35 percent moisture) before the first frost. Make the shift to early varieties in late May.

As the average date of the first killing frost moves later into October, the latest date for planting corn for grain moves later into June. In the northern third of the state, you can move the planting date later into June about the same number of days that the first frost falls after October 5. In the southern two-thirds of the state (this is especially true of the southern third), you can move the planting date proportionally later into June because temperatures will be higher during the remainder of the growing season.

In central Illinois, where the average killing frost occurs on October 15, early varieties of corn planted as late as July 5 have a 50-percent chance of maturing before frost. In southern Illinois, corn planted later in July usually will mature. However, planting later than July 5 to 10 is of questionable merit unless the need for grain or silage is especially great.

When corn planting is delayed past June 1 to 10, consider soybeans or sorghum as alternatives. These crops usually yield better than late-planted corn.

The vegetative period of soybeans is shortened as planting is delayed. Thus, soybeans can be planted later than corn with reasonable assurance that they will mature before frost. In northern Illinois, where the first killing frost is expected about October 5, early varieties, such as Chippewa 64 and Hark, may be expected to mature when planted as late as the end of June. The later varieties, such as Harcor and Corsoy, may be used until the middle of June.

In north central Illinois, you can plant Harcor and Corsoy until early July and you can use varieties of the maturity of Beeson until mid-June. In central Illinois, Wayne and varieties of similar maturity will mature when planted by mid-June. Use Amsoy 71, Corsoy, and Harcor until July 5 to 10. The growing season in southern Illinois is long enough that most of the varieties normally grown in the area will mature when planted as late as July 5 to 10.

When you must plant soybeans late, use the tallest variety that has a reasonable chance to mature. One of the problems with late-planted soybeans is short plant height with low podding. Dry weather aggravates this problem.

Other grain crops that mature in a short time and can be used in an emergency are sorghum and buckwheat.

Varieties of sorghum that will mature in 90 to 100 days are sometimes used for late planting. The penalty for planting sorghum late is often not as great as it is for corn and other crops.

If the crop is being grown as a cash crop, arrangements for a market should be made before planting. Some elevators prefer not to handle sorghum. Local livestock feeders or feed mills may be interested in the crop. Drying the grain is another problem often associated with sorghum. The grain should be harvested as soon as it is mature. Often this will be before the plant is dry, and the grain will be too wet to store without drying.

Buckwheat may mature in 75 to 90 days. It can be planted as late as July 10 to 15 in the northern part of the state and late July in southern Illinois. The crop is sensitive to both cold and hot weather. It will be killed by the first frost in the fall. Yields will be disappointingly low if it blooms during hot weather.

The market for buckwheat is limited unless you plan to use it for livestock feed. Be sure of a market before you plant it.

For more detailed treatment, see Circular 1181, *Crops for Emergency Planting*.

High Yields

Thick, vigorous stands of grasses and legumes are needed for high yields. A thick stand of grass will cover nearly all the ground. A thick stand of alfalfa is about 30 plants per square foot at the end of the seeding year, 10 to 15 plants per square foot the second year, and 5 to 7 plants per square foot for succeeding years.

Vigorous stands are created and maintained by choosing disease- and insect-resistant varieties that grow and recover quickly after harvest, fertilizing adequately, harvesting at the optimum time, and protecting the stand from insects.

Establishment

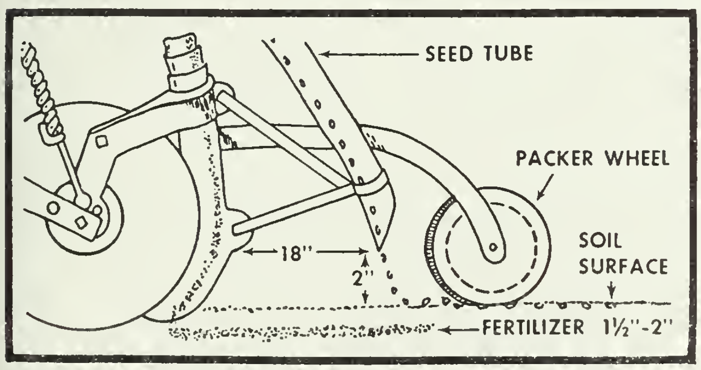
Spring seeding date for hay and pasture species in Illinois is late March or early April as soon as a seedbed can be prepared. An exception is when seedings are made in a fall-seeded winter annual companion crop. Seed hay and pasture species in winter annual companion crops, about the time of the last snow.

Spring seedings in spring oats should be done at the time the oats are seeded as early as a seedbed can be prepared.

Spring seedings are more successful in the northern half of Illinois than in the southern half. The frequency of success in the southern one-quarter to one-third of the state indicates late-summer seedings may be more desirable than spring seedings. Spring seedings are usually more successful than late-summer seedings in the northern quarter of Illinois.

Late-summer seeding date is August 10 in the northern quarter of Illinois, August 30 in central Illinois, and September 15 in the southern quarter of Illinois. Seedings should be made close to these dates and not more than five days later to assure that the plants become well established before winter. Extra early late summer seedings may suffer from drought following germination.

Seeding rates for hay and pasture mixtures are shown in Table 32 on page 33. These rates are for average conditions and when seeded with a companion crop in the spring or without a companion crop in late summer. Higher rates may be used to obtain high yields from alfalfa seeded without a companion crop in the spring. Higher seeding rates than described in Table 32 have proven economical in northern and central Illinois when alfalfa was seeded as a pure stand in early spring and two or three harvests in the seeding year were taken. Seeding alfalfa at 18 pounds per acre has produced 0.2 to 0.4 ton higher yield than seeding at 12 pounds per acre in northern and central Illinois, but not in south-central Illinois.



Placement of seed and high-phosphate fertilizer with grain drill. (Fig. 2)

The two basic methods of seeding are band seeding and broadcast seeding. Band seeding is placing a band of phosphate fertilizer (0-45-0) about two inches deep in the soil with a grain drill, then placing the forage seed on the soil surface directly above the fertilizer band (Fig. 2). The fertilizer should be covered with soil before the forage seeds are dropped. This process occurs naturally when soils are in good working condition. A press-wheel should roll over the forage seed to firm the seed into the soil surface. Many seeds will be placed one-fourth to one-half inch deep with this seeding method.

Broadcast seeding is spreading the seed uniformly over the prepared soil surface, then pressing the seed into the soil surface with a corrugated roller. The fertilizer is applied at the early stages of seedbed preparation. The seedbed is usually disked and smoothed with a harrow. Most soil conditions are too loose after these tillage operations and should be firmed with a corrugated roller before seeding. The best seeding tool for broadcast seeding is the double corrugated roller-seeder.

Which is the better seeding method? Illinois studies have shown that band seeding results in higher alfalfa yields than broadcast seedings for August and spring seedings at most locations. Seedings on low phosphorus-supplying soils yield more from band seeding than from broadcast seeding. Early seeding on cold, wet soils is favored by banded phosphorus fertilization. The greater yield from band seeding may be a response to abundant, readily available phosphorus from the banded fertilizer. Broadcast seedings may yield as high as band seedings when the soils are medium to high in phosphorus-supplying capacity and are well drained, so that they warm up quickly in the spring.

Forage crop seeds are small and should be seeded no deeper than one-fourth to one-half inch. These seeds need to be in close contact with soil particles. The double corrugated roller-seeder and the band seeder with press wheels roll the seed into contact with the soil and are the best known methods of seeding forages.

Fertilizing and Liming before or at Seeding

Lime. Apply lime at rates suggested in Figure 6, page 37. If rate requirements are in excess of 5 tons, apply

half before the primary tillage (in most cases, plowing) and half before the secondary tillage (harrowing, disking). Apply rates of less than 5 tons at one time, preferably after plowing, but either before or after is acceptable.

Nitrogen. No nitrogen should be applied for legume seedings on soils above 2.5 percent organic matter. Up to 20 pounds per acre may help assure rapid seedling growth of legume-grass mixtures on soils with less than 2.5 percent organic matter. When seeding a pure grass stand, 50 to 100 pounds nitrogen per acre in the seedbed is suggested. If band seeding, apply nitrogen with phosphorus through the grain drill. For broadcast seedings, apply broadcast with phosphorus and potassium.

Phosphorus. Apply all phosphorus at seeding time (Tables 46 and 48) or broadcast part of it with potassium. For band seeding, reserve a minimum of 30 pounds of P_2O_5 per acre to be applied at seeding time. For broadcast seeding, broadcast all the phosphorus with potassium, preferably after primary tillage and before final seedbed preparation.

Potassium. Fertilize before or at seeding. Broadcast application of potassium is preferred (Tables 47 and 48). For band seeding, you may safely apply a maximum of 30 to 40 pounds K_2O per acre in the band with phosphrous. The response to band fertilizer will be mainly from phosphorus unless the K soil test is very low (perhaps 100 or less). For broadcast seeding, apply all the potassium after the primary tillage. You can apply up to 600 pounds of K_2O per acre in the seedbed without damaging seedlings if the fertilizer is incorporated.

Fertilization

Nitrogen. See pages 40 through 48.

Phosphorus. This nutrient may be applied in large amounts, adequate for two to four years. The annual needs of a hay or pasture crop are determined from yield and nutrient content of the forage harvested (Table 48). Grasses, legumes, and grass-legume mixtures contain about 12 pounds of P_2O_5 (4.8 pounds of P) per ton of dry matter. Total annual fertilization needs include any needed build-up rate (Table 46) and the maintenance rate (Table 48).

Potassium. Grasses need large amounts of potassium to balance high rates of nitrogen fertilization, since potassium helps the plant convert nitrogen to protein. As nitrogen rates are increased, the percent nitrogen in the plant tissue also increases. However, if potassium is deficient, some nitrogen may remain in the plant as nonprotein nitrogen.

Legumes feed heavily on potassium. Potassium, a key element in maintenance of legumes in grass-legume stands, is credited with improving winter survival.

Annual potassium needs are determined from yield, nutrient content in the forage that is harvested, and nutrient build-up requirements of a particular soil (Tables 47 and 48). Grasses, legumes, and grass-legume mixtures contain about 50 pounds of K_2O (41.5 pounds of K) per ton of dry matter.

Boron. Symptoms of boron deficiency appear on second and third cuttings of alfalfa during drought periods in some areas of Illinois. But yield increases from boron fertilization have been infrequent. There is no recommendation for general application of boron in Illinois. If you suspect that there is a boron deficiency, topdress a test strip in your alfalfa fields with 30 pounds per acre of household borax (3.3 pounds of actual boron). For general application, have boron added to the phosphorus-potassium fertilizer.

Management

Seeding year. Hay crops and pastures seeded in a companion crop in the spring will benefit by early removal of the companion crop. Oats, wheat, or barley should be removed when the grain is in the milk stage. If these small grains are harvested for grain, it is important to remove the straw and stubble as soon as possible. As small grain yields increase, greater competition is being expressed on underseeded legumes and grasses, and fewer satisfactory stands are being established by the companion crop method. Forage seedings established with a companion crop may have one harvest taken by late August in northern Illinois and occasionally two harvests by September 10 in central Illinois and by September 25 in southern Illinois.

Spring-seeded hay crops and pastures without a companion crop should be ready for harvest 65 to 70 days after an early April seeding. Weeds very likely will need to be controlled about 30 days after seeding unless a preemergence herbicide was used. A postemergence herbicide, 2,4-DB, is effective against most broadleaf weeds. Grassy weeds are effectively controlled by Fusilade, Poast, and Velpar. Label clearance is pending for some of these herbicides. Follow label directions. Leafhoppers often become a problem between 30 and 45 days after an early April seeding and will need to be controlled to obtain a vigorous, high-yielding stand.

Second and third harvests may follow the first harvest at 35- to 40-day intervals. The last harvest of the season should be in late August for the northern quarter of Illinois, by September 10 for the central section, and by September 20 for the southern quarter of Illinois.

Established stands. Maximum dry-matter yield from alfalfa and most forages is obtained by harvesting or grazing the first cutting at nearly full bloom and harvesting every 40 to 42 days thereafter until September. This management produces a forage that is relatively low in digestibility. It is suitable for livestock on maintenance, will produce slow weight gain, and can be used in low-production feeding programs. High performance feeding programs need a highly digestible forage. The optimum compromise between high digestibility and dry-matter yield of alfalfa is to harvest or graze the first cutting at the late-bud-to-first flower stage and to make subsequent cuttings or grazings at 35-day intervals. Rotational grazing is essential to maintain legumes in pastures. A rotational grazing program should provide for 5 to 7 days of grazing and 30 to 35 days of rest.

Winter survival and vigor of spring growth are greatly affected by the time of the fall harvest. A high level of root reserves (sugars and starches) is needed. Root reserves decline following a harvest as new growth begins. About three weeks after harvesting, root reserves are depleted to a low level and the top growth is adequate for the photosynthesis to support the plant's needs for sugars. Root reserves are replenished gradually from this point until harvested, or until the plant becomes dormant in early winter. Harvests made in September and October affect late-fall root reserves of alfalfa more than do harvests made in the summer. After the September harvest, alfalfa needs a recovery period lasting until late October to restore root reserves. On well-drained soils in central and southern Illinois, a "late" harvest may be taken after plants have become dormant in late October.

Pasture Establishment

Many pastures can be established through a hay crop program. Seedings are made on a well-prepared seedbed that has been properly fertilized. If the hay crop is intended to become a pasture, the desired legume and grass mixture should be seeded. When grasses and legumes are seeded together, 2,4-DB is the herbicide that can be used for broadleaf weed control. 2,4-DB is most effective when applied about 30 days after seeding, when the legumes are 2 to 4 inches tall, and the weeds are less than 4 inches tall.

Pasture Renovation

Pasture renovation usually means changing the plant species in a pasture to increase the pasture productivity and quality. Improving the fertility of the soil is basic to this effort. A soil test helps identify the need for lime, phosphorus, and potassium — the major nutrients important to establishing new forage plants.

Before seeding new legumes or grasses into a pasture, competition from existing pasture plants must be reduced. Tilling, overgrazing, and herbicides, used singly or in combination, have proven useful in subduing existing pasture plants.

For many years, tilling, plowing, and heavy discing have been used to renovate pastures, but success has been variable. Major criticisms have been that tilling can cause erosion, that the pasture supply for the year of seeding is usually limited, and that a seeding failure would leave no available permanent vegetation for pasturing or soil protection.

No-till seeding of new pasture plants into existing pastures began when herbicides and suitable seeders were developed. The practice of using a herbicide to subdue existing pasture plants and then seeding with a no-till seeder has proven very successful in many research trials and farm seedings. Following are eight basic steps to no-till pasture renovation.

1. Graze the pasture intensively for 20 to 30 days before the seeding date to reduce the vigor of existing pasture plants.

2. Lime and fertilize, using a soil test as a guide. Soil pH should be between 6.5 and 7.0. Desired phosphorus and potassium test levels vary with soil type; phosphorus should be in the 40 to 50 pound-per-acre test range, and potassium should be in the 260 to 300 pound-per-acre range. For more information, see the chapter on soil testing and fertility.

3. Apply a herbicide to subdue the vegetation 1 or 2 days before seeding. Paraquat and Roundup are approved for this purpose.

4. Seed the desired species, using high-yielding varieties. Alfalfa and red clover are the higher-yielding legumes and are often the only species seeded into a pasture that has a desirable grass species and in which Paraquat is going to be used in preference to Roundup. Seed with a no-till drill that places the seed in contact with the soil.

5. Seed in early spring throughout the northern two-thirds of Illinois, and in late August throughout the southern three-fourths of Illinois.

6. Apply insecticides as needed. Soil insects that eat germinating seedlings are more prevalent in southern Illinois than in northern Illinois, and a soil insecticide may be needed. Furadan has been approved for this use. Leafhoppers will be present throughout Illinois in early summer and throughout most of the growing season. They must be controlled, especially in spring-seeded pastures, since they are devastating to new alfalfa seedlings. Several insecticides are approved; see Cooperative Extension Circular 899 for more information. Well-established alfalfa plants are injured but not killed by leafhoppers; red clover and grass plants are not attacked by leafhoppers.

7. Initiate grazing 60 to 70 days after spring seedings and not until the next spring for late-August seedings. Spring-seeded alfalfa and red clover should be at about 50 percent bloom. Alfalfa and red clover that are seeded in late August should be in the late-bud to first-flower stage of growth when grazing begins. Use rotational grazing. Graze 5 to 7 days and rest 28 to 30 days; for slightly lower-quality and lower-yielding pasture, graze 10 days and rest 30 days.

8. Fertilize pastures annually on the basis of estimated crop removal. Each ton of dry matter from a pasture contains approximately 12 pounds of phosphate (P_2O_5) and 50 to 60 pounds of potash (K_2O). Do not use nitrogen on established pastures where the vegetation is 30 percent or more alfalfa and/or red clover.

Pasture Seeding Mixture Selection

Alfalfa is the best single species for increasing yield and improving the quality of pastures in Illinois. Red clover produces very well in the first two years after seeding, but contributes very little from then on. Birdsfoot trefoil establishes slowly and increases to 40-50 percent of the yield potential of alfalfa. Mixtures of alfalfa at 8 pounds and red clover at 4 pounds per acre,

and birdsfoot trefoil at 4 pounds and red clover at 4 pounds per acre, have successfully demonstrated high yield. Red clover diminishes from the stand at about the third year, and the more persistent species, alfalfa or birdsfoot trefoil, increases to maintain a high yield level for the third and subsequent years.

Management to Improve Pastures

Many pastures can be improved in yield and quality by fertilization. The soil pH is basic to any fertilization program. Pasture grasses tolerate a lower soil pH than hay and pasture legumes. For pastures that are primarily grass, a minimal pH should be 6.0. A pH of 6.2-6.5 is more desirable because other nutrients are more efficiently utilized in this pH range than at lower pH values. Lime should be applied to correct the soil acidity to ½ plow depth. The duration of this liming is half as long as when a full rate is applied and plowed into the plow layer. Consequently, pastures will usually require liming more often (but at lower rates) than cultivated fields.

Table 25. — Leading Alfalfa Varieties Tested Three Years or More in Illinois, 1984

Variety	Bacterial wilt	Percentage of yield of check varieties		
		Northern Illinois	Central Illinois	Southern Illinois
Acclaim	R[a]	.....	109.87	.....
Apollo II	R	114.86	109.85	.....
Armor	R	110.26	105.30	.....
Blazer	R	114.63	108.61	117.30
Cimarron	R	111.40	106.40	104.22
DeKalb Br 120	R	113.82	109.01	106.33
DeKalb Br Advantage	R	113.00	109.65	.....
Endure (NAPB 108)	R	112.10	.....	.....
Epic	R	108.76	108.32	103.14
Futura	R	107.93	104.34	107.48
G-2815	R	114.50	113.00	100.40
G-7730	R	111.80	110.10	100.30
ICO-10	R	.....	109.97	.....
ICO-2	R	.....	109.57	.....
ICO-25	R	.....	108.07	.....
ICO-3	R	.....	110.20	.....
Jubilee	R	.....	114.70	.....
Magnum	R	104.74	107.94	109.33
Mercury	R	116.10	110.10	.....
Northmoor	R	.....	96.80	109.10
Oneida	R	108.27	96.50	101.58
Peak	R	110.87	109.69	.....
Perry	R	99.96	105.38	105.27
Pioneer Br 520	R	106.50	103.90	111.00
Pioneer Br 524	R	106.37	104.34	105.51
Pioneer Br 526	R	111.58	108.98	100.50
Pioneer Br 532	R	110.17	107.63	102.38
Thunder	R	.....	109.60	.....
Voris A-77	R	107.14	107.55	105.05
WL 315	R	97.80	107.21	105.43
WL 316	MR[b]	104.30	105.72	107.51
Wrangler	R	.....	110.70	.....

[a] R = resistant.
[b] MR = moderately resistant.

Phosphorus and potassium needs are assessed by a soil test. Without a soil test, the best guess is to apply what the crop removes. Pasture crops remove approximately 12 pounds P_2O_5 (phosphate) and 50 pounds K_2O (potash) per ton of dry matter. Very productive pastures yield 5 to 6 tons of dry matter per acre. Moderately productive pastures yield 3-5 tons, and less productive pastures yield 1 to 3 tons.

Rotation grazing of grass pastures results in greater production (animal weight gain per acre) than continuous grazing except for Kentucky bluegrass pastures. Pastures including legumes need rotation grazing to maintain the legumes in the pasture. A rotation grazing plan that works well is 5 to 7 days grazing with 28 to 30 days rest, requiring 5 to 6 fields. This plan provides high quality pasture needed by growing animals and dairy cows. A less intense grazing plan for beef cow herds, dry cows, and stocker animals is 10 days grazing with 30 days rest, requiring 4 fields.

Weed control is usually needed in pastures. Clipping pastures after each grazing cycle helps in weed control. Herbicides may be needed for problem areas. 2,4-D and Banvel are effective on most broadleaved weeds. Banvel is more effective than 2,4-D for most conditions but also has more restrictions. Do not graze dairy animals or feed harvested forage from these fields until 60 days after treatment with Banvel. Remove meat animals from Banvel-treated pastures 30 days prior to slaughter. 2,4-D restrictions apply to milk cows, which should not be grazed on treated pasture for 7 days after treatment. Thistles can usually be controlled by 2,4-D or Banvel, although repeated applications of the herbicide may be necessary. Multiflora rose can be controlled with Banvel applied in early spring, when the plant is actively growing, but before flower bud formation.

Species and Varieties

Alfalfa is the highest yielding perennial forage crop suited to Illinois, and its nutritional qualities are nearly unsurpassed. Alfalfa is an excellent hay crop species and can be used in pastures with proper management as mentioned above.

Bloat in ruminant animals often is associated with alfalfa pastures. Balancing soil fertility, including grasses in mixtures with alfalfa, maintaining animals at good nutritional levels, and using bloat-inhibiting feed amendments are methods to reduce or essentially eliminate the bloat hazard.

Many varieties of alfalfa are available. Some have been privately developed; some have been developed at public institutions. Private varieties usually are marketed through a few specific dealers. Not all varieties are available in Illinois.

An extensive testing program has been under way at the University of Illinois for many years. The listing of alfalfa variety performance in Table 25 is based on test

Table 26. — Red Clover Variety Yields

Variety	Anthracnose resistance		Powdery mildew resistance	Amount of dry matter					
	Northern	Southern		DeKalb 1983-84	Monmouth 1983-84	Urbana 1983-84	Perry 1983-84	Browns-town 1981-83	Dixon Springs 1983
				Tons per acre					
Arlington	R[a]	...	R	3.15	4.22	3.75	2.20	...	3.56
E688	T[b]	R	R	...	...	...	...	4.22	...
Flare	MR[c]	R	R	3.45	4.40	4.22	2.70	4.26	3.70
Florie	R	R	R	3.32	4.41	3.70	2.58	4.30	3.49
Mega	R	R	R	...	...	...	...	4.10	...
Mor Red	HR[d]	MR	HR	3.32	4.24	3.52	2.18	...	3.30
Redland	MR	R	R	3.20	4.67	3.89	...	4.32	...
Redland II	R	R	R	3.42	4.80	3.94	2.82	4.26	3.88
Redman	R	MR	R	3.52	4.54	...	...	4.24	3.50
Ruby	R	R	...	3.39	4.57	4.08	2.64	4.27	3.87

[a] R = resistant
[b] T = tolerant
[c] MR = moderately resistant
[d] HR = high resistance

data information compiled since 1961. Some varieties have been tested every year since 1961; others have been tested only three or four years. However, each variety appearing in this list has been in test at least three years.

Bacterial wilt is one of the major diseases of alfalfa in Illinois. Stands of susceptible varieties usually decline severely in the third year of production and may die out in the second year under intensive harvesting schedules. Moderate resistance to bacterial wilt enables alfalfa to persist up to four or five years. Varieties listed as resistant usually persist beyond five years.

Other diseases and insects are problems and some varieties have particular resistance to these problems. You should question your seed supplier concerning these attributes of the varieties being offered to you.

Red clover is the second most important hay and pasture legume in Illinois. It does not have the yield potential of alfalfa under good production conditions, but can persist in more acid soil conditions and under more shade competition than alfalfa. Although red clover is physiologically a perennial, root and crown diseases limit the life of red clover to two years. New varieties, including Arlington, Kenstar, and Redland, have increased resistance to root and crown diseases and are expected to be productive for at least three years. See Table 26.

Red clover does not have as much seedling vigor or as rapid a seedling growth rate as alfalfa. Therefore, red clover does not fit into a spring seeding without a companion crop program as well as alfalfa.

Red clover has more shade tolerance at the seedling stage than alfalfa. Therefore, red clover is recommended for most pasture renovation mixtures where shading by existing grasses occurs.

There are fewer varieties of red clover than of alfalfa. Many are from the U.S. Department of Agriculture and state experiment stations. Private breeders are also active in red clover variety development.

Mammoth red clover is being grown on about 17 percent of the clover acreage. Yields of mammoth red clover has been lower than yields of most of the improved varieties of medium red clover.

Ladino clover is an important legume in pastures, but it has received little attention recently because of its short-lived character. The very leafy nature of ladino makes it an excellent legume for swine. It is a very high-quality forage for ruminant animals also, but problems of bloat frequently are experienced.

Ladino lacks drought tolerance because its root system is shallower than that of red clover or alfalfa.

Birdsfoot trefoil has been popular in permanent pastures in northern Illinois. It has a long life but becomes established very slowly. Seedling growth rate is much slower than that of alfalfa or red clover.

A root rot has made birdsfoot trefoil a short-lived crop throughout southern Illinois. The variety Dawn may have adequate resistance to persist throughout the state (see Table 27 for variety yields).

Rooting depth of birdsfoot trefoil is shallower than alfalfa. Thus birdsfoot trefoil is not as productive during drought.

Crownvetch is well known for protecting very erosive soil areas. As a forage crop, crownvetch is much slower in seedling emergence, seedling growth rate, early season growth, and recovery growth than alfalfa or red clover. Growth rate is similar to that of birdsfoot trefoil. The potential of crownvetch as a hay or pasture plant seems restricted to very rough sites and soils of low productivity.

Sainfoin is a legume introduced into the western United States from Russia. This species has failed to become well enough established in Illinois tests to make valid comparisons with alfalfa, red clover, and others. Observations indicate that sainfoin has a slow growth and recovery growth rate and is not well suited to the humid conditions of Illinois.

Hairy vetch is an annual legume that has limited value as a hay or pasture species. Low production and

Table 27. — Birdsfoot Trefoil Variety Yields, 1980-82

Variety	DeKalb 1980-81	Urbana 1982	Perry 1982	Brownstown 1981-82
	Amount of dry matter			
	Tons per acre			
Carroll	2.83	4.03	2.83	3.49
Dawn	2.91	3.01	2.91	3.76
Empire	2.81	3.39	2.85	3.36
Fargo	2.87	3.48	2.86	3.09
Fergus	3.57	4.82	3.28	3.92
Leo	2.89	3.52	2.96	3.33
Mackinaw	...	3.81	2.67	3.49
Maitland	...	3.67	3.20	3.59
Missouri-20	3.61	3.72	3.18	3.93
Norcen	3.24	4.42	3.11	3.46
Viking	3.10	3.80	3.12	3.53

Table 28. — Timothy Variety Yields, 1979-82

Variety	DeKalb 1979-82	Urbana 1979-81	Brownstown 1980-82	Dixon Springs 1980-81
	Amount of dry matter			
	Tons per acre			
FS 954	3.23	3.75	...	2.68
FS 955	3.19	3.45	...	2.62
Itasca	3.12	3.78	4.35	2.86
Pronto	2.90	2.93	4.61	2.76
Toro	3.33	3.93	5.16	3.10

its viny nature have discouraged much use. Hairy vetch may reseed itself and become a weedy species in small grain fields.

Lespedeza is a popular annual legume in the southern third of Illinois. It comes on strong in mid-summer when most other forage plants are at their low ebb in production. It survives on soils of low productivity and is low yielding. It does not produce as well as a good stand of alfalfa even in mid-summer, nor will it encroach on a good alfalfa stand. As alfalfa or other vigorous pasture plants fade out of a pasture, lespedeza may enter.

Timothy is the most popular hay and pasture grass in Illinois. Timothy is not as high yielding and has less mid-summer production than smooth bromegrass. It is a cool season species and is best suited to the northern half of Illinois. There are promising new varieties (Table 28).

Smooth bromegrass is probably the most widely adapted, high-yielding grass species for northern and central Illinois. Smooth bromegrass combines well with alfalfa or red clover. It is productive, but it has limited summer production when moisture is lacking and temperatures are high. It produces well in spring and fall and can utilize high-fertility programs. There are a few improved varieties, and breeding work continues (Table 29).

Orchardgrass is one of the most valuable grasses for hay and pasture use in Illinois. It is adapted throughout the state, being marginally winter hardy for the northern quarter of the state. Orchardgrass heads out relatively early in the spring and thus should be combined with early flowering alfalfa varieties. Orchardgrass is one of the more productive grasses in mid-summer. It is a high-yielding species and several varieties are available (Table 30).

Reed canarygrass is not widely used, but it has growth attributes that deserve consideration. Reed canarygrass is the most productive of the tall, cool season perennial grasses that are well suited to Illinois hay and pasture lands. It tolerates wet soils but also is one of the most drought-resistant grasses and can utilize high fertility. It

Table 29. — Smooth Bromegrass Variety Yields, 1979-82

Variety	DeKalb 1979-82	Urbana 1979-81	Brownstown 1980-82	Dixon Springs 1980-81
	Amount of dry matter			
	Tons per acre			
Barton	3.20	3.51	4.72	2.68
Baylor	3.28	4.08	4.71	2.64
Blair	3.52	3.92	4.68	2.88
Fox	3.13	3.30	4.26	2.60
FS Beacon	3.25	3.58	4.83	2.40
Regro	...	...	4.72	2.44
Sac	3.05	3.54	4.58	2.56

Table 30. — Yields of Orchardgrass, Reed Canarygrass, Tall Fescue, and Perennial Ryegrass, 1979-82

Variety	DeKalb 1979-82	Urbana 1979-81	Brownstown 1980-82	Dixon Springs 1980-81
	Amount of dry matter			
	Tons per acre			
ORCHARDGRASS				
Able	2.68	3.15	4.96	2.68
Crown	2.81	3.23	5.19	2.63
Dart	3.04	3.48	5.31	2.89
FS 863	2.61	3.34	5.30	2.76
Hallmark	2.98	3.30	5.27	2.88
Hawk	...	...	5.40	...
Lotto	2.72	3.35	...	2.44
Potomac	2.53	3.44	5.16	2.52
Sterling	3.18	3.47	5.21	2.83
REED CANARYGRASS				
Flare	3.43	3.53	5.21	2.74
Rise	3.02	3.85	5.11	2.64
Vantage	3.14	3.45	5.30	2.72
TALL FESCUE				
Balade	3.10	3.50	4.40	2.58
Fawn	3.45	4.20	4.37	3.30
Forager	3.14	3.65	4.44	2.98
Kenhy	3.73	4.08	4.90	2.76
Kenwell	3.30	3.95	4.81	2.80
Ky 31	3.51	4.20	4.44	3.04
MO-96	3.00	3.71	4.40	2.50
PERENNIAL RYEGRASS				
Reveille	2.62	...	3.99	2.10
Variant	2.50	...	3.78	1.94
Cumalda	...	...	...	2.08

is coarser than orchardgrass or bromegrass but not as coarse as tall fescue. Grazing studies indicate that reed canarygrass will produce good gains equal to those of bromegrass, orchardgrass, or tall fescue under proper grazing management. Reed canarygrass should be considered for grazing during spring, summer, and early fall. Cool temperatures and frost retard growth and induce dormancy earlier than with tall fescue, smooth bromegrass, or orchardgrass. New low-alkaloid varieties may improve animal performance on reed canarygrass.

Tall fescue is a high-yielding grass. It is outstanding in performance when used properly and is a popular grass for beef cattle in southern Illinois. It is especially useful for winter pasture because it grows well in cool weather. It is also most palatable during the cool seasons of spring and late fall. Evidence indicates that a fungus living within the plant tissue (endophyte) has a major influence on the lower palatability and digestibility of this grass during the warm summer months. Fungus-free or low-in-fungus varieties are available. Tall fescue is marginally winter hardy when used in pastures or hay crops in the northern quarter of the state.

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids are annual grasses that are very productive in late summer. These grasses need to be seeded each year on a prepared seedbed. The total season production from these grasses may be less than that from perennial grasses with equal fertility and management. However, these annual grasses fill a need for quick, supplemental pastures as green feed. These tall, juicy grasses are difficult to make into high-quality hay. Sudangrass and sudangrass hybrids have finer stems than the sorghum-sudan hybrids and thus will dry more rapidly; they should be chosen for hay purposes over the sorghum-sudan hybrids. Crushing the stems with a hay conditioner will help speed drying.

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids produce prussic acid, a compound that is toxic to livestock. Prussic acid is the common name for hydrogen cyanide (HCN). The compound in sorghum plants that produces HCN is dhurrin. Two enzymes are required to hydrolyze dhurrin to HCN. The microflora in the rumen of ruminant animals are capable of enzymatic breakdown of dhurrin. Dhurrin concentration is highest in young tissue, more in leaves than in stems, more in grain or forage sorghums than in sorghum-sudangrass hybrids, and less in sudangrass hybrids and in sudangrass.

Sudangrass and sudangrass hybrids are considered safe for grazing when they are 18 inches tall. The sorghum-sudangrass hybrids should be 24 inches tall before grazing. Very hungry cattle or sheep should be fed other low prussic acid potential feeds before turning them onto a lush sudangrass or sorghum-sudangrass pasture. This will prevent rapid grazing and a sudden influx of forage that contains prussic acid. These animals can tolerate low levels of prussic acid because they can metabolize and excrete the HCN.

Frost on the sorghum family crops results in the plant enzymes coming into contact with dhurrin and in a rapid release of HCN. For this reason, it is advisable to remove grazing ruminant livestock from freshly frosted sudangrasses and sorghums. When the frosted plant material is thoroughly dry, grazing can be resumed. Drying usually takes 3 to 5 days. Grazing after this time should be observed closely for new tiller growth, which will be high in dhurrin, and livestock should be removed when new tiller growth is being grazed.

The sorghums can be ensiled. The fermentation of ensiling reduces the prussic acid potential very substantially. This is the safest method of using feed that has a questionable high prussic acid potential.

As explained earlier, it is difficult to make high-quality hay from sudangrass, sudangrass hybrids, or sorghum-sudangrass hybrids because their large juicy stems dry slowly. Harvesting these crops as hay is a safe way of using a crop with questionable high levels of prussic acid potential.

Toxic levels of prussic acid (HCN) vary. Some workers report toxicity at 20 mg HCN per 100 grams of tissue dry weight, where others report moderate toxicity at 50 to 75 mg HCN per 100 grams of tissue dry weight. Laboratory diagnostic procedures can determine relative amounts of HCN potential. An alkaline picrate solution is commonly used for detection of HCN in plant tissue.

Millets are warm season annual grasses that are drought tolerant. Four commonly known millets are pearlmillet (*Pennisetum typhoides*), browntop millet (*Panicum ramosum*), foxtail or Italian millet (*Setaria italica*), and Japanese millet (*Echinochloa crusgalli*). Pearlmillet has been evaluated in grazing trials and is a suitable alternative for summer annual pastures.

Pearlmillet requires a warmer soil for rapid establishment than does sudangrass. Seedings should be delayed until the soil temperature in the seedbed averages 70°F.

Pearlmillet does not have a prussic acid potential as does sundangrass, nor is pearlmillet as susceptible to leaf diseases. Pearlmillet is more drought tolerant than sudangrass, thus producing more pasture during hot dry periods of late summer than does sudangrass.

Forage Mixtures

Mixtures (Table 32) of legumes and grasses usually are desired. Yields tend to be greater with mixtures than with either the legume or the grass alone. Grasses are desirable additions to legume seedings to fill in where the legume ceases to grow, to reduce the bloat hazard with ruminant animals, to reduce late winter-heaving damage, to reduce soil erosion, to increase the drying rate, and perhaps to improve animal acceptance. Mixtures of two or three well chosen species are usually higher yielding than mixtures of five or six species in which some of the species are not particularly well suited to the soil, climate, or use.

Table 31. — Hay, Pasture, and Silage Crop Varieties

Crop	Variety	Origin	Use
Ladino clover	Merit	Iowa	Pasture
Birdsfoot trefoil	Carroll	Iowa	Hay and pasture
	Dawn	Missouri	Pasture
	Empire	New York	Pasture
	Fargo	North Dakota	Hay and pasture
	Fergus	Kentucky	Hay and pasture
	Leo	Canada	Hay and pasture
	Missouri-20	Missouri	Hay and pasture
	Norcen	North Central States	Hay and pasture
	Viking	New York	Hay and pasture
Crownvetch	Chemung	New York	Erosion and pasture
	Emerald	Iowa	Erosion and pasture
	Penngift	Pennsylvania	Erosion and pasture
Smooth bromegrass	Barton	Land O'Lakes, Inc.	Hay and pasture
	Baylor	Rudy Patrick Company	Hay and pasture
	Blair	Rudy Patrick Company	Hay and pasture
	Fox	Minnesota	Hay and pasture
	FS Beacon	Land O'Lakes, Inc.	Hay and pasture
	Lincoln	Nebraska	Hay and pasture
	Saratoga	New York	Hay and pasture
	Sac	Wisconsin	Hay and pasture
	Southland	Oklahoma	Hay and pasture
Orchardgrass	Able	Farm Forage Research Cooperative	Hay and pasture
	Boone	Kentucky	Hay and pasture
	Crown	North American Plant Breeders	Hay and pasture
	Dart	Land O'Lakes, Inc.	Hay and pasture
	Dayton	Rudy Patrick Company	Hay and pasture
	FS 863	FS Services	Hay and pasture
	Hallmark	Farm Forage Research Cooperative	Hay and pasture
	Hawk	North American Plant Breeders	Hay and pasture
	Ina	Northrup, King and Company	Hay and pasture
	Jackson	Virginia	Hay and pasture
	Lotto	Holland	Hay and pasture
	Napier	Rudy Patrick Company	Hay and pasture
	Pennlate	Pennsylvania	Hay and pasture
	Potomac	Maryland	Hay and pasture
	Sterling	Iowa	Hay and pasture
Tall fescue	Alta	Oregon	Pasture
	Aronde	Holland	Pasture
	Balade	Holland	Pasture
	Fawn	Oregon	Pasture
	Forager	Farm Forage Research Cooperative	Pasture (low endophyte fungus)
	Kenmont	Kentucky	Pasture
	Kenhy	Kentucky	Pasture (more palatable, low endophyte fungus)
	Kenwell	Kentucky	Pasture (more palatable)
	Ky-31	Kentucky	Pasture
	Mo-96	Missouri	Pasture (more digestible)
	Pastuca	Holland	Pasture
	Johnstone	Kentucky	Pasture (low endophyte fungus)
Timothy	Clair	Kentucky	Hay
	Climax	Indiana	Hay
	FS 954	FS Services	Hay
	FS 955	FS Services	Hay
	Itasca	Minnesota	Hay
	Pronto	Pride Company, Inc.	Hay
	Timfor	Northrup, King and Company	Hay
	Toro	Rudy Patrick Company	Hay
	Verdant	Wisconsin	Hay

Table 32. — Forage Seed Mixture Recommendations, All Entries Given in Pounds per Acre

For Hay Crops

Moderate to well-drained soils

Central, Northern Illinois		Central, Southern Illinois	
Alfalfa	12	Alfalfa Orchardgrass	8 6
Alfalfa Bromegrass	8 6	Alfalfa Tall fescue	8 6
Alfalfa Bromegrass Timothy	8 4 2		
Alfalfa Timothy	8 4		

Poorly drained soils

Central, Northern Illinois		Central, Southern Illinois	
Red clover Timothy	8 4	Red clover Bromegrass	8 6
Red clover Bromegrass	8 6		
Alsike clover Timothy	5 4	Reed canarygrass Alsike clover	8 4
Reed canarygrass Alsike clover	8 3	Tall fescue Alsike clover	6 4
Birdsfoot trefoil Timothy	5 2	Redtop Alsike clover	4 4

Droughty soils

Central, Northern Illinois		Central, Southern Illinois	
Alfalfa Bromegrass	8 6	Alfalfa Orchardgrass	8 4
Alfalfa Tall fescue[a]	8 6	Alfalfa Tall fescue	8 6
		Alfalfa Bromegrass	8 6

For Horse Pastures

Moderate to well-drained soils

Central, Northern Illinois		Southern Illinois	
Alfalfa Smooth bromegrass Kentucky bluegrass	8 6 2	Alfalfa Orchardgrass Kentucky bluegrass	8 3 5

Poorly drained soils

Central, Northern Illinois		Southern Illinois	
Smooth bromegrass Kentucky bluegrass Timothy Ladino clover	6 2 2 ½	Orchardgrass Kentucky bluegrass Ladino clover	6 5 ½

Central Illinois

Moderate to well-drained soils

Alfalfa Orchardgrass Kentucky bluegrass	8 3 2

Poorly drained soils

Orchardgrass Kentucky bluegrass Ladino clover	6 2 ½

For Hog Pastures

All soil types, anywhere in Illinois

Alfalfa Ladino clover	8 2

For Rotation and Permanent Pastures

Moderate to well-drained soils

Central, Northern Illinois		Southern Illinois	
Alfalfa Bromegrass Timothy	8 5 2	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Orchardgrass[a] Timothy	8 4 2	Tall fescue Ladino clover	8 ½
Orchardgrass[a] Ladino clover	6 ½	Alfalfa Bromegrass Timothy	8 6 2
Red clover Ladino clover Orchardgrass[a]	8 ½ 4	Orchardgrass Ladino clover	6 ½
Red clover Ladino clover Tall fescue	8 ½ 6-8	Tall fescue	10
Birdsfoot trefoil Timothy	5 2	Orchardgrass	8
Bromegrass Ladino clover	8 ½	Red clover Ladino clover Orchardgrass	8 ½ 4
Tall fescue	10	Red clover Ladino clover Tall fescue	8 ½ 6-8
Orchardgrass[a]	8		

Poorly drained soils

Central, Northern Illinois		Southern Illinois	
Alsike clover Ladino clover Timothy	3 ¼ 4	Alsike clover Tall fescue Ladino clover	2 8 ½
Birdsfoot trefoil Timothy	5 2	Reed canarygrass Alsike clover Ladino clover	8 3 ½
Reed canarygrass Alsike clover Ladino clover	8 3 ¼-½		
Alsike clover Tall fescue Ladino clover	2 8 ½		

Droughty soils

Central, Northern Illinois		Southern Illinois	
Alfalfa Bromegrass	8 5	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Tall fescue	8 6	Red clover Ladino clover Orchardgrass[a]	8 ½ 4
Red clover Ladino clover Orchardgrass	8 ½ 4	Red clover Ladino clover Tall fescue	8 ½ 6-8
Red clover Ladino clover Tall fescue	8 ½ 6-8		

For Pasture Renovation

Moderate to well-drained soils

Central, Northern Illinois		Southern Illinois	
Alfalfa Red clover	8 4	Alfalfa Red clover	8 4

Poorly drained soils

Central, Northern Illinois		Southern Illinois	
Birdsfoot trefoil Red clover	4 4	Alsike Ladino clover Red clover	2 ½ 4

[a] Central Illinois only.

Pollination of Legume Seeds

Illinois has been an important producer of legume seeds, particularly red clover. Illinois ranks third in the nation in seed production. Yields vary widely from year to year. Warm, dry summers favor seed production. Low yields are in part caused by inadequate pollination by bees. Only during the second bloom do honey bees visit red clover in high enough numbers to pollinate it while they collect pollen and nectar. In experiments on the Agronomy Farm at Urbana, honey bees collected 54 to 99 percent of their daily pollen intake from red clover between July 12 and August 3.

Bumblebees also pollinate red clover, but they cannot be relied on because they are not always present and their numbers are unpredictable. Even the presence of honey bees in the vicinity of red clover fields can no longer be assured, because of insufficient numbers of hives in Illinois.

If you produce red clover seed, do so on the second crop and use at least two colonies of honey bees per acre within or beside the field. On large fields place them in two or more groups. Do not rely on bees present in the neighborhood, because pollination and seed set decrease rapidly as distance between the hives and the crop becomes greater than 800 feet. Bring a sufficient number of hives to the field as soon as it comes into bloom. When all factors for seed production are favorable, proper pollination of red clover by honey bees has the potential of doubling or tripling seed yields.

White and yellow sweetclovers are highly attractive to bees and other insects. However, probably because of the large number of blossoms, their seed yields increase when colonies of honey bees are placed nearby. Yields up to 1,400 pounds per acre have been produced in the Midwest by using six colonies of bees per acre. One or two hives per acre will give reasonably good pollination.

Crownvetch does not attract bees and requires special techniques to produce a commercial crop of seed. Best yields have been obtained by bringing strong, new hives of bees to the fields every 8 to 10 days. In place of such special provisions, one or more hives of honey bees per acre of crownvetch are of value.

The effects of insect pollination on annual lespedeza, such as Korean, have not been investigated. However, the perennial lespedezas require insect pollination to produce a crop of seed, and honey bees can be used.

Many legumes grown in Illinois for pasture or for purposes other than seed production are visited by honey bees and other bee pollinators. Alfalfa and birdsfoot trefoil as well as alsike, white, and ladino clovers all provide some pollen and nectar and, in turn, are pollinated to varying degrees.

Soybeans are visited by honey bees at Urbana in July and August during their bloom. The beans are a major source of honey in the state. In tests at Urbana, honey bee visits to soybeans did not increase seed yield over that of plants caged to exclude bees. Other studies have indicated that some varieties increase yields as a result of increasing honey bee visits during flowering.

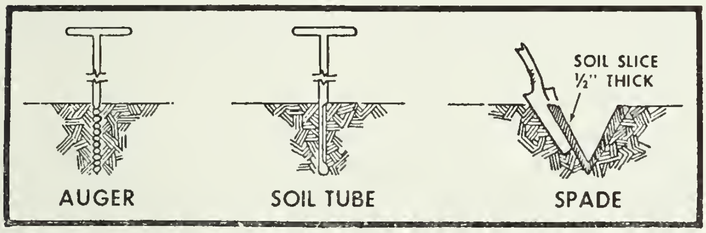
SOIL TESTING AND FERTILITY

Soil Testing

Soil testing is the most important single guide to the profitable application of fertilizer and lime. When soil test results are combined with information about the nutrients that are available to the various crops from the soil profile, the farmer has a reliable basis for planning his fertility program on each field.

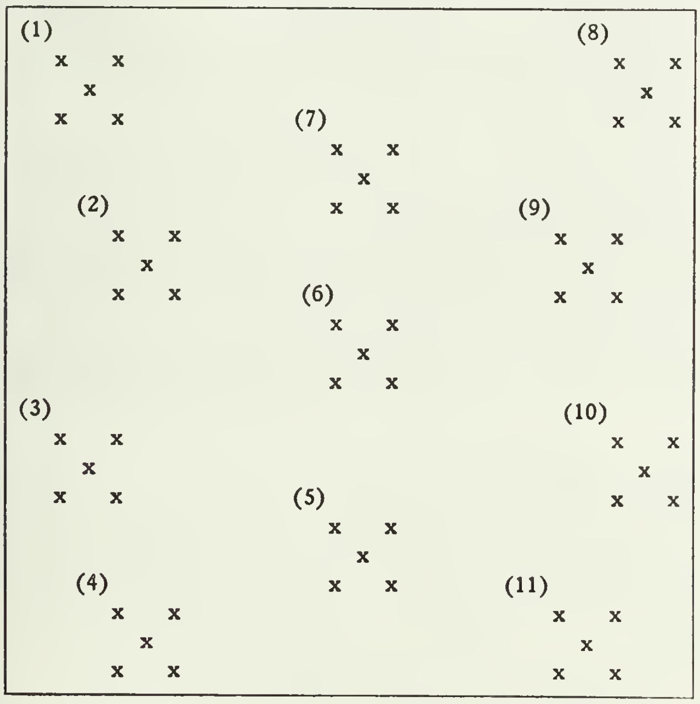
Traditionally, soil testing has been used to decide how much lime and fertilizer to apply. Today, with increased emphasis on the environment, soil tests are also a logical tool to determine areas where adequate or excessive fertilization has taken place. It is just as important to determine where fertilizers should not be used.

How to sample. A soil tube is the best implement to use for taking soil samples, but a spade or auger also can be used (Fig. 3). One composite sample from every 3 to 4 acres is suggested. Five soil cores taken with a tube will give a satisfactory composite sample of approximately 1 to 2 cups in size. You may follow a regular pattern as indicated in Figure 4.



How to take soil samples with an auger, soil tube, and spade. (Fig. 3)

40-acre field



Soil-sampling patterns for a 40-acre field. For a 20-acre field, eliminate 8 through 11. (Fig. 4)

The most common mistake is to take too few samples to represent the fields adequately. Following shortcuts in sampling may produce unreliable results and lead to higher fertilizer costs or lower returns or both.

It is important to collect soil samples from the proper depth. This is particularly true in fields where reduced tillage systems have been used, as these systems result in less mixing of lime and fertilizer than does a tillage system that includes a moldboard plow. This stratification of nutrients has not adversely affected crop yields. However, misleading soil test results may be obtained if samples are not taken at the proper depth of 7 to 9 inches.

When to sample. Sampling every four years is strongly suggested. Late summer and fall are the best seasons to collect soil samples from the field. Potassium test results are most reliable during these times. Sampling frozen soil or within two weeks after the soil is frozen should be avoided.

Where to have soil tested. Illinois has about 65 commercial soil-testing services. If you do not know of any, your county extension adviser or fertilizer dealer can advise you of availability of soil testing in your area.

Information to accompany soil samples. The best fertilizer recommendations made are those that are based both on soil test results and a knowledge of the field conditions that will affect nutrient availability. Since the person making the recommendation does not know the conditions of each field, it is important that you provide adequate information with each sample.

This necessary information includes cropping intention for the next four years; the nature of the soil (clay, silty, or sandy; light or dark colored; level or hilly; eroded; well drained or wet; tiled or not; deep or shallow); fertilizer you have been using (amount and grade); whether the field was limed in the past two years; and yield goals for all proposed crops.

What tests to have made. Illinois soil-testing laboratories are equipped to test soils for pH (soil acidity), P_1 (available phosphorus), and K (potassium). No test for nitrogen has proven successful enough to justify a recommendation by University of Illinois agronomists.

Soil tests for certain secondary and micronutrients may warrant consideration under particular circumstances. These tests may be useful for:

1. *Trouble shooting.* Diagnosing symptoms of abnormal growth. Paired samples representing areas of good and poor growth are needed for analyses.

2. *"Hidden-hunger checkup."* Identifying deficiencies before symptoms appear. However, soil tests are of little value in indicating marginal levels of secondary and micronutrients when crop growth is apparently normal. For this purpose, plant analysis may yield more information.

Tests may be made for most of the secondary and micronutrients, but their interpretation is less reliable than interpretation of tests for lime, phosphorus, or potassium. Complete field history and soil information are especially important in interpreting the results of tests for micronutrients.

Plant Analysis

Plant analyses can be useful in diagnosing problems, in identifying hidden hunger, and in determining whether current fertility programs are adequate. They often provide more reliable measures of micronutrient and secondary nutrient problems than do soil tests.

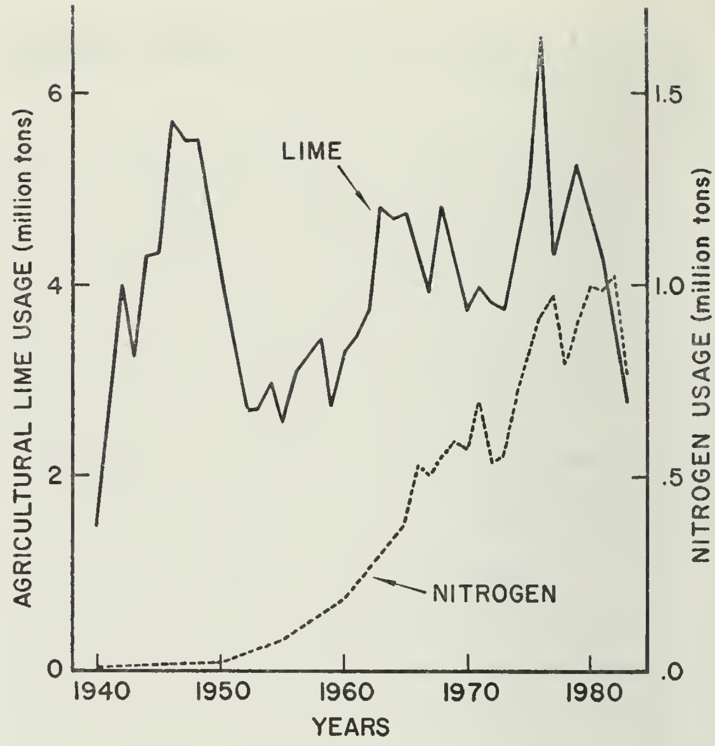
When making a plant analysis, select the correct plant part and handle it carefully. For corn, sample the leaf opposite and below the ear from several plants sometime between tasseling and silking. For soybeans, sample the most recent fully developed leaves and petioles at early podding. Samples taken later will not indicate the nutritional status of the plant. After you collect the samples, deliver them immediately to the laboratory. They should be air dried if they cannot be delivered immediately or if they are going to be shipped to a laboratory.

Environmental factors may complicate the interpretation of plant analysis data. The more information one has concerning a particular field, the more reliable the interpretation will be. Suggested critical nutrient levels are provided in Table 33. Levels below these may indicate a nutrient deficiency.

Lime

Soil acidity is one of the most serious limitations to crop production. Acidity is created by a removal of bases in harvested crops, by the leaching of bases, and by an acid residual that is left in the soil from nitrogen fertilizers. Over the last several years, limestone usage has remained relatively constant, but crop yields and nitrogen fertilizer use have increased markedly (Fig. 5).

Illinois farmers presently are using about 4 pounds of agricultural lime per pound of nitrogen applied. This is the approximate amount required to neutralize the acidity that results from the use of 1 pound of nitrogen as ammonia, ammonium nitrate, nitrogen solutions, or urea. However it is slightly less than one half the amount needed if the nitrogen source is ammonium sulfate (9 pounds of lime are needed to neutralize the acidity from 1 pound of nitrogen as ammonium sulfate). At the present limestone usage rate, no lime is being added to correct the acidity that is created by the removal of bases nor the acidity created in prior years, which had not been corrected. A soil test every four years is the best way to check on soil acidity levels.



Usage of agricultural lime and commercial nitrogen fertilizer, 1940-1980. (Fig. 5)

The effect of soil acidity on plant growth. There are several ways soil acidity affects plant growth. Whenever soil pH is low (i.e., acidity is high), several situations may exist.

1. The concentration of soluble metals may be toxic. Excess solubility of aluminum and manganese has been established experimentally.

2. Populations and activities of the organisms responsible for transformations involving nitrogen, sulfur, and phosphorus may be altered.

3. Calcium may be deficient. This usually occurs when the cation-exchange capacity of the soil is extremely low.

Table 33. — Suggested Critical Plant Nutrient Levels

Crop	Plant part	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
Corn	Leaf opposite and below the ear at tasseling	percent						ppm				
		2.9	0.25	1.90	0.40	0.15	0.15	15	25	15	5	10
Soybeans	Fully developed leaf at early podding	...	0.25	2.00	0.40	0.25	0.15	15	30	20	5	25

4. Symbiotic nitrogen fixation is impaired greatly on acid soils. The symbiotic relationship requires a narrower range of soil reaction than is necessary for growth of plants not relying on N fixation.

5. Acidic soils are poorly aggregated and have poor tilth. This is particularly true for soils low in organic matter.

6. Availability of mineral elements to plants may be improved. Figure 6 shows the relationship between soil pH and nutrient availability. The wider the white bar, the greater the nutrient availability. For example, phosphorus availability is greatest in the pH range between 6.0 and 7.5, dropping off rapidly below 6.0. Molybdenum availability is increased greatly as soil acidity is decreased. Molybdenum deficiencies usually can be corrected by liming.

Suggested pH goals. For cropping systems with alfalfa and clover, aim for a pH of 6.5 or above unless the soils are pH 6.2 or above without ever having been limed. In those soils, neutral soil is just below plow depth and it probably will not be necessary to apply limestone.

For cash-grain systems (no alfalfa or clover), maintaining a pH of at least 6.0 is a realistic goal. If the soil test shows that the pH is 6.0, apply limestone to prevent a drop in pH below 6.0. Farmers may choose to raise the pH to still higher levels. After the initial investment, it costs little more to maintain a pH of 6.5 than it does to maintain 6.0. The profit over a 10-year period will be affected very little, since the increased yield will about offset the original cost of the extra limestone (2 or 3 tons per acre) plus interest.

Research indicates that a profitable yield response from raising the pH above 6.5 in cash-grain systems is unlikely.

Liming treatments based on soil tests. The limestone requirements in Figure 7 are based on these assumptions:

1. A nine-inch plowing depth. If plowing is less than nine inches deep, reduce the amount of limestone; if more than nine inches, increase the lime rate proportionately.

2. Typical fineness of limestone: 10 percent greater than 8-mesh; 30 percent that pass an 8-mesh and are held on 30-mesh; 30 percent that pass a 30-mesh and are held on 60-mesh; and 30 percent that pass a 60-mesh. If the limestone is not as fine as indicated above or if a quick effect is desired, apply more limestone than indicated in the charts.

3. A calcium carbonate equivalent (total neutralizing power) of 90 percent. The rate of application may be adjusted according to the deviation from 90.

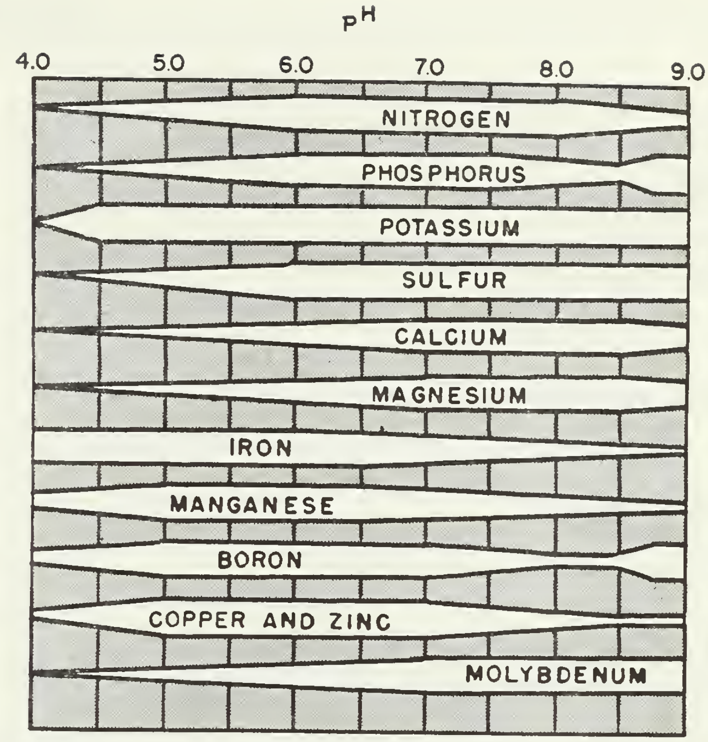
Instructions for using Figure 7 are as follows:

1. Use Chart I for grain systems and Chart II for alfalfa, clover, or lespedeza.

2. Decide which soil class fits your soil:

A. Dark-colored silty clays and silty clay loams.

B. Light- and medium-colored silty clays and silty clay loams; dark-colored silt and clay loams.



Available nutrients in relation to pH. (Fig. 6)

C. Light- and medium-colored silt and clay loams; dark- and medium-colored loams; dark-colored sandy loams.

D. Light-colored loams; light- and medium-colored sandy loams; sands.

E. Muck and peat.

Color is related to organic matter. Light-colored soils usually have less than 2.5 percent organic matter; medium-colored soils have 2.5 to 4.5 percent organic matter; dark-colored soils have above 4.5 percent organic matter; sands are excluded.

Limestone quality. Limestone quality is measured by neutralizing value and fineness of grind. The neutralizing value of limestone is measured by its calcium carbonate equivalent: the higher this value, the greater the limestone's ability to neutralize soil acidity. Similarly, the finer limestone is ground, the faster it will neutralize soil acidity. Relative efficiency factors have been determined for various particle sizes (Table 34). Research has shown little, if any, practical difference in effectiveness between material that passes through a 60-mesh sieve and that which passes through a finer-mesh sieve.

The quality of limestone is defined as its effective neutralizing value (ENV). This value can be calculated for any liming material using the efficiency factors in Table 34 and the calcium carbonate equivalent for the limestone in question. The "typical" limestone on which Figure 7 is based has an ENV of 46.35 for 1 year and 67.5 for 4 years.

To calculate the ENV for any particular limestone for 1 and 4 years after application, use the worksheet on the following page.

Evaluation for 1 Year after Application

			Efficiency factor	
% of particles greater than 8-mesh	$= \frac{\_\_\_\_}{100}$	×	5	=
% of particles that pass 8-mesh and are held on 30-mesh	$= \frac{\_\_\_\_}{100}$	×	20	=
% of particles that pass 30-mesh and are held on 60-mesh	$= \frac{\_\_\_\_}{100}$	×	50	=
% of particles that pass 60-mesh	$= \frac{\_\_\_\_}{100}$	×	100	=
			Total fineness efficiency	____

$$\text{ENV} = \text{total fineness efficiency} \times \frac{\%\ \text{calcium carbonate equivalent}}{100}$$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (46.35)}}{\text{ENV of sampled limestone (\_\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 7) = ____ tons of sampled limestone needed per acre

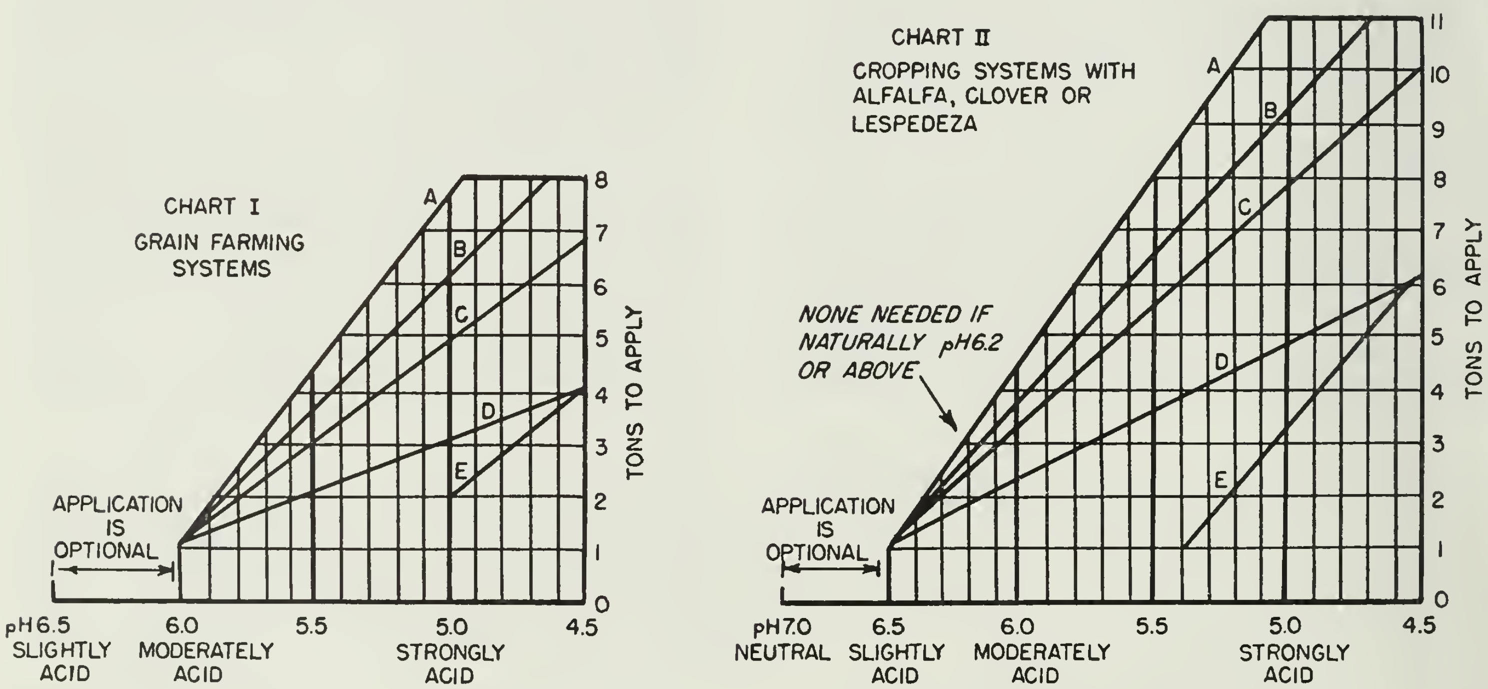
Evaluation for 4 Years after Application

			Efficiency factor	
% of particles greater than 8-mesh	$= \frac{\_\_\_\_}{100}$	×	15	=
% of particles that pass 8-mesh and are held on 30-mesh	$= \frac{\_\_\_\_}{100}$	×	45	=
% of particles that pass 30-mesh and are held on 60-mesh	$= \frac{\_\_\_\_}{100}$	×	100	=
% of particles that pass 60-mesh	$= \frac{\_\_\_\_}{100}$	×	100	=
			Total fineness efficiency	____

$$\text{ENV} = \text{total fineness efficiency} \times \frac{\%\ \text{calcium carbonate equivalent}}{100}$$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (67.5)}}{\text{ENV of sampled limestone (\_\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 7) = ____ tons of sampled limestone needed per acre



Suggested limestone rates based on soil type, pH, and cropping system. (Fig. 7)

Table 34. — Efficiency Factors for Various Limestone Particle Sizes

Particle sizes	Efficiency factor	
	1 year after application	4 years after application
Greater than 8-mesh	5	15
8- to 30-mesh	20	45
30- to 60-mesh	50	100
Passing 60-mesh	100	100

As an example, assume a limestone that has a calcium carbonate equivalent of 86.88 percent and that has 13.1 percent that is greater than 8-mesh, 40.4 percent that passes 8-mesh and is held on 30-mesh, 14.9 percent that passes 30-mesh and is held on 60-mesh, and 31.6 percent that passes 60-mesh. Assume that you need 3 tons of typical limestone per acre (according to Figure 7).

1 Year

$$\frac{13.1\%}{100} \times 5 = 0.65$$

$$\frac{40.4\%}{100} \times 20 = 8.08$$

$$\frac{14.9\%}{100} \times 50 = 7.45$$

$$\frac{31.6\%}{100} \times 100 = 31.6$$

Total fineness efficiency 47.78

$$\text{ENV} = 47.78 \times \frac{86.88}{100} = 41.51$$

$$\frac{46.35}{41.51} \times 3 = 3.35 \text{ tons per acre}$$

4 Years

$$\frac{13.1\%}{100} \times 15 = 1.96$$

$$\frac{40.4\%}{100} \times 45 = 18.18$$

$$\frac{14.9\%}{100} \times 100 = 14.9$$

$$\frac{31.6\%}{100} \times 100 = 31.6$$

Total fineness efficiency 66.64

$$\text{ENV} = 66.64 \times \frac{86.88}{100} = 57.9$$

$$\frac{67.5}{57.9} \times 3 = 3.5 \text{ tons per acre}$$

At rates up to 6 tons per acre, if high initial cost is not a deterrent, you may apply the entire amount at one time. If cost is a factor and the amount of limestone needed is 6 tons or more per acre, apply it in split applications of about two-thirds the first time and the remainder three or four years later.

Liquid lime. Results to date indicate that liquid lime and dry lime are equivalent in effectiveness when applied at equal rates of effective neutralizing value. Since liquid lime is composed of particles less than 60-mesh, one uses an efficiency factor of 100 to determine its limestone quality. Use the following equation to calculate the rate of liquid lime needed.

$$\frac{\text{ENV of typical limestone (use 67.5)}}{\text{100 (fineness efficiency factor)} \times \frac{\text{\% calcium carbonate equivalent, dry matter basis}}{100} \times \frac{\text{\% dry matter}}{100}}$$

$\times$ tons of limestone needed per acre = tons of liquid lime needed per acre.

As an example, assume a lime need of 3 tons per acre (based on Figure 7) and liquid lime that is 50 percent water and that has a calcium carbonate equivalent of 97 percent on a dry matter basis. The rate of liquid lime needed would be calculated as follows.

$$\frac{67.5}{100 \times \frac{97}{100} \times \frac{100\text{-}50}{100}} \times 3 = 4.18 \text{ tons of liquid lime per acre}$$

Lime incorporation. Lime does not react with acid soil very far from the particle. However, special tillage operations to mix lime with soil usually are not necessary; this has been true with conventional tillage that included use of the moldboard plow. Systems of tillage that use a chisel plow or field cultivator rather than a moldboard plow may necessitate a reexamination of soil acidity within the root zone.

Calcium-Magnesium Balance in Illinois Soils

Soils in northern Illinois usually contain more magnesium than those in central and southern sections because of the high magnesium content in the rock from which the soils developed and because northern soils are geologically younger. This has caused some to wonder whether the magnesium level is too high. There have been reports of suggestions that either gypsum or low-magnesium limestone from southern Illinois quarries should be applied. However, no one operating a soil-testing laboratory or selling fertilizer in Illinois has put forth research to justify concern over too narrow a calcium:magnesium ratio.

On the other hand, there is justifiable concern over a soil magnesium level that is low, because of its relationship with hypomagnesemia, a prime factor in grass tetany or milk fever in cattle. This is more relevant to forage production than to grain production. Very high potassium levels (500+) combined with low soil magnesium levels contribute to low-magnesium forages. Research

data to recommend specific magnesium levels are not available. However, levels of magnesium less than 40 pounds per acre on sands and 150 pounds per acre on silt loam are regarded as low.

Calcium and magnesium levels of agricultural limestone vary between different quarries in the state. Dolomite limestone (material with an appreciable magnesium content as high as 21.7 percent MgO or 46.5 percent $MgCO_3$) occurs predominantly in the northern three tiers of Illinois counties, including Kankakee County on the east and an additional area in Calhoun County. Limestone in the remainder of the state is dominantly calcitic (high calcium, although it is not uncommon to have 1 to 3 percent $MgCO_3$).

For farmers following a grain system of farming, there are no agronomic reasons to recommend either that farmers in northern Illinois bypass local sources, which are medium to high in magnesium, and pay a premium for low-magnesium limestone from southern Illinois or that farmers in southern Illinois order limestone from northern Illinois quarries because of magnesium content.

For farmers with a livestock program or who produce forages in the claypan and fragipan regions of the south where soil magnesium levels may be marginal, it is appropriate to use a soil test to verify the conditions and to use dolomite limestone or supplemental magnesium fertilization.

Nitrogen

Harvested crops remove more nitrogen than any other nutrient from Illinois soils. Erosion reduces the nitrogen content of soils because the surface soil is richest in nitrogen and erodes first. Further nitrogen losses occur as a result of denitrification and leaching. About 40 percent of the original nitrogen and organic matter content has been lost from typical Illinois soils since farming began.

The use of nitrogen fertilizer is necessary if Illinois agriculture is to continue to provide adequate crop production to aid in meeting the ever-increasing world demand for food. With the world shortage of nitrogen fertilizer and energy, all nitrogen fertilizers should be used in the most efficient manner possible. Factors that influence efficiency of fertilizer use are discussed in the following sections.

Rate of Application

Corn. Yield goal is one of the major considerations to use in determining the optimum rate of nitrogen application for corn. These goals should be established for each field, taking into account the soil type and management level under which the crop will grow.

For Illinois soils, suggested productivity index values are given in Illinois Cooperative Extension Service Circular 1156, *Soil Productivity in Illinois.* Yield goals are presented for both basic and high levels of management. For fields that will be under exceptionally high management, a 15-to-20-percent increase of the values given for high levels of management would be reasonable. Annual variations in yield of 20 percent above or below the productivity index values are common because of variations in weather conditions. However, applying nitrogen fertilizer for yields possible in the most favorable year will not result in maximum net return when averaged over all years.

The University of Illinois Department of Agronomy has conducted research trials designed to determine the optimum nitrogen rate for corn under varying soil and climatic conditions.

The results of these experiments show that average economic optimum nitrogen rates varied from 1.22 to 1.32 pounds of nitrogen per bushel of corn produced when nitrogen was spring applied (Table 35). The lower rate of application (1.22 pounds) would be recommended at a corn-nitrogen price ratio (corn price per bushel to nitrogen price per pound) of between 10:1 and 20:1 and the higher rate (1.32 pounds) at a price ratio of 20:1 or greater.

Table 35. — Economic Optimum Nitrogen Rate Experimentally Determined for Eight Locations as Affected by Corn-Nitrogen Price Ratios

Location and rotation	Corn-nitrogen price ratio			
	10:1		20:1	
	Optimum yield (bu./acre)	Optimum N rate (lb./bu.)	Optimum yield (bu./acre)	Optimum N rate (lb./bu.)
Brownstown (continuous corn)	83	1.30	86	1.47
Carthage (continuous corn)	144	1.22	147	1.29
DeKalb (continuous corn)	141	1.28	143	1.31
Urbana (continuous corn)	171	1.17	173	1.24
Average of continuous corn		1.24		1.33
Dixon (corn-soybeans)	131	1.37	134	1.58
Hartsburg (corn-soybeans)	156	1.19	157	1.27
Oblong (corn-soybeans)	123	1.11	126	1.23
Toledo (corn-soybeans)	123	1.12	124	1.20
Average of corn-soybeans		1.20		1.32
Average of all locations		1.22		1.32

As would be expected, the nitrogen requirement was lower at those sites having a corn-soybean rotation than at sites with continuous corn because of the nitrogen contribution from soybeans (see nitrogen rate adjustment section).

With the exception of Dixon, which was based on limited data, Brownstown and DeKalb had the highest nitrogen requirement per bushel of corn produced. This higher requirement may be in part the result of the higher denitrification losses that frequently have been observed at Brownstown and DeKalb.

Based on these results, examples of the recommended rate of nitrogen application for selected Illinois soils under a high level of management are indicated in Table 36.

Soybeans. Based on average Illinois corn and soybean yields from 1971-73 and average nitrogen content of the grain for these two crops, the total nitrogen removed per acre by soybeans was greater than that removed by corn (soybeans, 132 pounds of nitrogen per acre; corn, 82 pounds of nitrogen per acre). However, recent research results from the University of Illinois indicate that when properly nodulated soybeans were grown at the proper soil pH, symbiotic fixation was equivalent to 63 percent of the nitrogen removed in harvested grain. Thus, net nitrogen removal by soybeans was less than that of corn (corn, 82; soybeans, 49).

This net removal of nitrogen by soybeans in 1973 was equivalent to 39 percent of the amount of fertilizer nitrogen used in Illinois. On the other hand, symbiotic fixation of nitrogen by soybeans in Illinois (367,000 tons of N) was equivalent to 67 percent of the fertilizer nitrogen used in Illinois.

Even though there is a rather large net nitrogen removal from soil by soybeans (49 pounds of nitrogen per acre), research at the University of Illinois has not generally indicated any soybean yield increase caused by either residual nitrogen remaining in the soil or nitrogen applied for the soybean crop.

Table 36. — Nitrogen Recommendations for Selected Illinois Soils Under High Level of Management

Soil type	Corn-nitrogen price ratio	
	10:1	20:1
	Nitrogen recommendation (lbs./acre)	
Muscatine silt loam	205	220
Ipava silt loam	200	215
Sable silty clay loam	190	205
Drummer silty clay loam	185	200
Plano silt loam	185	200
Hartsburg silty clay loam	175	190
Fayette silt loam	155	170
Clinton silt loam	155	170
Cowden silt loam	145	160
Cisne silt loam	140	150
Bluford silt loam	125	135
Grantsburg silt loam	115	125
Huey silt loam	80	85

A. Residual from nitrogen applied to corn (Table 37). Soybean yields at four locations were not increased by residual nitrogen remaining in the soil even when nitrogen rates as high as 320 pounds per acre had been applied to corn the previous year.

B. Nitrogen on continuous soybeans (Table 38). After 18 years of continuous soybeans at Hartsburg, yields were unaffected by nitrogen rates.

C. High rates of added nitrogen (Table 39). In 1968 a study was started at Urbana using moderate rates of nitrogen. Rates were increased in 1969 so that the high rates could furnish more than the total nitrogen needs of soybeans. Yields were not affected by nitrogen in 1968, but a tendency toward a yield increase occurred in 1969 and 1970 with 400 pounds per acre of nitrogen. However, this rate of nitrogen would not be economical at current prices.

Wheat, oats, and barley. The rate of nitrogen application to be used on wheat, oats, and barley is dependent on soil type, variety to be grown, and future cropping intentions (Table 40). Light-colored (low organic matter) soils require the highest rate of nitrogen application as they have a low capacity to supply nitrogen. Deep, dark-colored soils require relatively low rates of nitrogen

Table 37. — Soybean Yields at Four Locations as Affected by N Applied to Corn the Preceding Year (Four-Year Average)

N applied to corn (lb./acre)	Soybean yield (bu./acre)				
	Aledo	Dixon	Elwood	Kewanee	Average
0	48	40	37	40	41
80	49	40	36	38	41
160	48	39	36	40	41
240	48	42	36	40	41
320	48	42	36	37	41

Table 38. — Yield of Continuous Soybeans With Rates of Added N at Hartsburg

N (lb./acre/year)	Soybean yield (bu./acre)	
	1968-71	1954-71
0	43	37
40	42	36
120	43	37

Table 39. — Soybean Yields as Affected by High Rates of Nitrogen

Nitrogen (lb./acre)			Soybean yield (bu./acre)		
1968	1969	1970	1968	1969	1970
0	0	0	54	53	40
40	200	200	54	57	41
80	400	400	56	57	45
120	800	800	53	55	42
160	1,600	1,600	55	34	36

Table 40. — Recommended Nitrogen Application Rates for Wheat, Oats, and Barley

Soil situation	Organic matter content	Fields with alfalfa or clover seeding: Stiff-strawed varieties	Fields with alfalfa or clover seeding: Other adapted wheat and oat varieties and all varieties of barley	Fields with no alfalfa or clover seeding: Stiff-strawed varieties	Fields with no alfalfa or clover seeding: Other adapted wheat and oat varieties and all varieties of barley
		Nitrogen (lb./acre)			
Soils low in capacity to supply nitrogen: inherently low in organic matter (forested soils)	<2%	50–70	40–60	70–90	50–70
Soils medium in capacity to supply nitrogen: moderately dark-colored soils	2–3%	30–50	20–40	50–70	30–50
Soils high in capacity to supply nitrogen: all deep, dark-colored soils	>3%	20–30	0	40–50	20–30

application for maximum yields. Estimates of organic matter content for soils of Illinois can be obtained from Agronomy Fact Sheet SP-36, "Average Organic Matter Content in Illinois Soil Types," or by using University of Illinois publication AG-1941, "Color Chart for Estimating Organic Matter in Mineral Soils."

Higher rates of application can be used on the stiff-strawed wheat varieties such as Abe, Arthur, Arthur 71, Caldwell, Hart, Pike, Roland, and Scotty than on the other varieties, which are more susceptible to lodging. Nearly all recommended oat varieties grown in Illinois have good straw strength; thus, higher nitrogen rates are recommended. Most varieties of barley grown in Illinois are weak strawed and, thus, susceptible to lodging.

Some wheat in Illinois serves as a companion crop for legume or legume-grass seedings. On those fields, it is best to apply nitrogen fertilizer at slightly below the optimum rate, as unusually heavy vegetative growth of wheat competes unfavorably with the young forage seedlings (Table 40).

The introduction of nitrification inhibitors and improved application equipment now provide two options for the application of nitrogen to wheat. Research has shown that a fall application of the entire amount of nitrogen needed with a nitrification inhibitor resulted in yields equivalent to that obtained when a small portion of the total need was fall applied and the remainder was applied in early spring. Producers who are frequently delayed in applying nitrogen in the spring because of muddy fields may wish to consider fall application with a nitrification inhibitor. If wet fields are not normally experienced in the spring, either system of application will provide equivalent yields.

The amount of nitrogen needed for good fall growth is not large because the total uptake in roots and tops prior to cold weather is not likely to exceed 30 to 40 pounds per acre.

Hay and pasture grasses. The species grown, period of use, and yield goal determine optimum nitrogen fertilization (Table 41). The lower rate of application is recommended on those fields where an inadequate stand or moisture limits production.

Kentucky bluegrass is shallow rooted and susceptible to drouth. Consequently, the most efficient use of nitrogen by bluegrass is from an early spring application. September applications are second choice. September fertilization stimulates both fall and early spring growth.

Orchardgrass, smooth bromegrass, tall fescue, and reed canarygrass are more drouth tolerant than bluegrass and can use higher rates of nitrogen more effectively than bluegrass. Because more uniform pasture production is obtained by splitting high rates of nitrogen, two or more applications are suggested.

Make the first nitrogen application in March in southern Illinois, early April in central Illinois, and mid-April in northern Illinois if extra spring growth can be utilized. If spring growth is adequate without extra nitrogen, the first application can be delayed until after the first harvest or grazing cycle to distribute production more uniformly throughout the summer. However, total production likely will be less if nitrogen is applied after first harvest rather than in early spring. The second application of nitrogen usually is made after the first harvest or first grazing cycle. However, this application can be deferred until August or early September to stimulate fall growth.

Table 41. — Nitrogen Fertilization of Hay and Pasture Grasses

Species	Time of application: Early spring	After first harvest	After second harvest	Early September
	Nitrogen (lb./acre)			
Kentucky bluegrass.....	60–80			(see text)
Orchardgrass..........	75–125	75–125		
Smooth bromegrass.....	75–125	75–125		50[a]
Reed canarygrass.......	75–125	75–125		50[a]
Tall fescue for winter use		100–125	100–125	50[a]

[a] Optional if extra fall growth is needed.

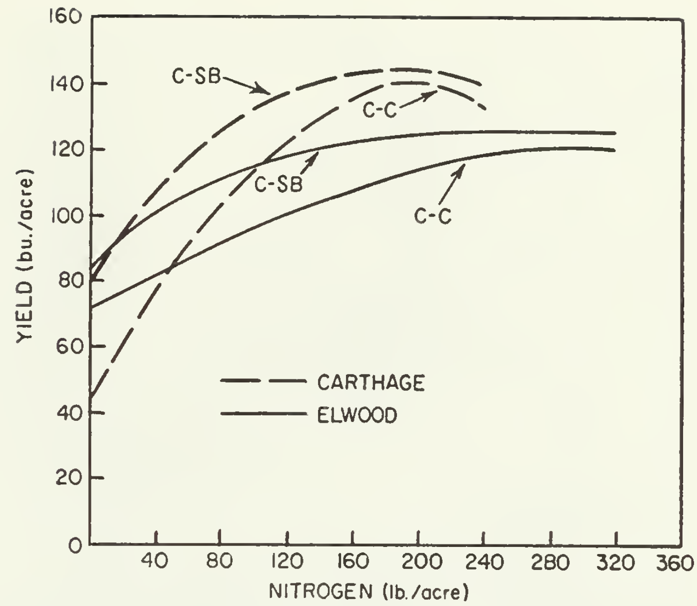
Legume-grass mixtures should not receive nitrogen if legumes make up 30 percent or more of the mixture. The main objective is to maintain the legume, so emphasis should be on phosphorus and potassium rather than on nitrogen.

After the legume has declined to less than 30 percent of the mixture, the object of fertilizing is to increase the yield of grass. The suggested rate of nitrogen is about 50 pounds per acre when legumes make up 20 to 30 percent of the mixture.

Rate Adjustments

In addition to determining nitrogen rates, consideration should be given to other agronomic factors that influence available nitrogen. These adjustments include past cropping history and the use of manure (Table 42), as well as date of planting.

Experiments conducted at the Carthage experimental field comparing nitrogen requirements of continuous corn and corn following soybeans indicate a soil nitrogen contribution of 30 to 40 pounds per acre at the lower rates of applied nitrogen and 20 to 30 pounds per acre at the higher rates of nitrogen application (Fig. 8). At Elwood, the yield differential between continuous corn and corn-soybeans continues to widen at higher rates of nitrogen application. It is doubtful that this yield differential is entirely the result of nitrogen contributions from the soybeans. The contribution of legumes, either soybeans or alfalfa, to wheat will be less than the contribution to corn because the oxidation of the organic nitrogen from these legumes will not be as rapid in early spring, when the nitrogen needs of small grain are greatest, as it is in the summer, when nitrogen needs of corn are greatest.



Effect of crop rotation and applied nitrogen on corn yield. (Fig. 8)

Table 42. — Adjustments in Nitrogen Recommendations

Crop to be grown	Factors resulting in reduced nitrogen requirement						
	After soybeans	1st year after alfalfa or clover, Plants/sq ft.			2nd year after alfalfa or clover, Plants/sq. ft.		Manure
		5	2-4	<2	5	<5	
	Nitrogen reduction (lb./acre)						
Corn	40	100	50	0	30	0	5[a]
Wheat	10	30	10	0	0	0	5[a]

[a] Nitrogen contribution in pounds per ton of manure.

Table 43. — Average Composition of Manure

Kind of animal	Nutrients (lb./ton) Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Dairy cattle	11	5	11
Beef cattle	14	9	11
Hogs	10	7	8
Chicken	20	16	8
Dairy cattle (liquid)	5(26)[a]	2(11)	4(23)
Beef cattle (liquid)	4(21)	1(7)	3(18)
Hogs (liquid)	10(56)	5(30)	4(22)
Chicken (liquid)	13(74)	12(68)	5(27)

[a] Parenthetical numbers are pounds of nutrients per 1,000 gallons.

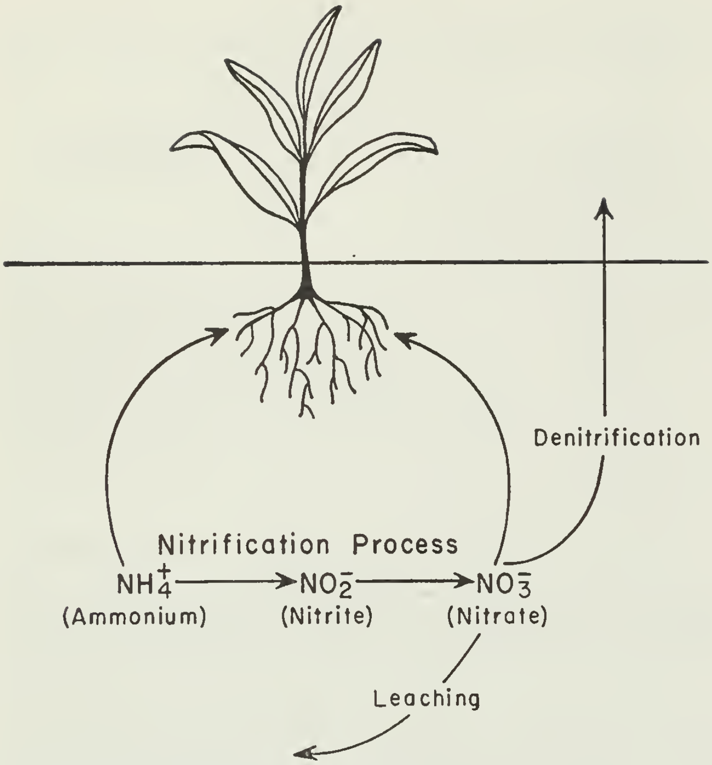
There is some variation in the nutrient content of manure that is dependent on source and method of handling (Table 43). Additionally, the availability of the total nitrogen content will vary, depending on method of application. When incorporated during or immediately after application, approximately 50 percent of the total nitrogen in dry manure and 60 to 75 percent of the total nitrogen in liquid manure will be available for the crop that is grown during the year following manure application.

Research at the Northern Illinois Research Center for several years showed that as planting was delayed, less nitrogen fertilizer was required for most profitable yield. Based upon that research, Illinois agronomists suggest that for each week of delay in planting after the optimum date for the area, the nitrogen rate can be reduced 20 pounds per acre down to 80 to 90 pounds per acre as the minimum for very late planting in a corn-soybean cropping system. Suggested reference dates are April 10 to 15 in southern Illinois, April 20 to May 1 in central Illinois, and May 1 to 10 in northern Illinois. This adjustment is, of course, possible only if the nitrogen is sidedressed.

Because of the importance of the planting date, farmers are encouraged not to delay planting just to apply nitrogen fertilizer: plant, then sidedress.

Reactions in the Soil

Efficient use of nitrogen fertilizer requires an understanding of how nitrogen behaves in the soil. Key points to consider are the change from ammonium (NH_4^+) to nitrate (NO_3^-) and movements and transformations of nitrate.



Nitrogen reactions in the soil. (Fig. 9)

A high percentage of the nitrogen applied in Illinois is in the ammonium form or converts to ammonium (anhydrous ammonia and urea, for example) soon after application. Ammonium nitrogen is held by the soil clay and organic matter and cannot move very far until it nitrifies (changes from ammonium to nitrate). In the nitrate form, nitrogen can be lost by either denitrification or leaching (Fig. 9).

Denitrification. Denitrification is believed to be the main process by which nitrate and nitrite nitrogen are lost, except on sandy soils, where leaching is more important. Denitrification involves only nitrogen in the form of either nitrate (NO_3^-) or nitrite (NO_2^-).

The amount of denitrification depends mainly on (1) how long water stands on the soil surface or how long the surface is saturated; (2) the temperature of the soil and water; (3) the pH of the soil; and (4) the amount of energy material available to denitrifying organisms.

When water stands on the soil or when the surface is completely saturated in fall or early spring, nitrogen loss is likely to be small because (a) much nitrogen is still in the ammonium rather than nitrate form, and (b) the soil is cool and denitrifying organisms are not very active.

Many fields in east central Illinois and to a lesser extent in other areas have low spots where surface water collects at some time during the spring or summer. The flat clay-pan soils also are likely to be saturated, though not flooded. Sidedressing would avoid the risk of spring loss on these soils, but would not affect midseason loss. Unfortunately, these are the soils on which sidedressing is difficult in wet years.

Denitrification is difficult to measure in the field, but several laboratory studies show that it can happen very quickly. At temperatures that are common in midsummer, most nitrate nitrogen can be denitrified within three to five days at pH 6.0 or above.

Leaching. In silt loams and clay loams, one inch of rainfall moves down about five to six inches, though some of the water moves farther in large pores through the profile and carries nitrates with it.

In sandy soils, each inch of rainfall moves nitrates down about one foot. If the total rainfall at one time is more than six inches, little nitrate will be left within rooting depth on sands.

Between rains, there is some upward movement of nitrates in moisture that moves toward the surface as the surface soil dries out. The result is that the penetration of nitrates is difficult to predict from the cumulative total of rainfall.

When trying to estimate the depth of leaching of nitrates in periods of very intensive rainfall, two points need to be considered. First, the rate at which water can enter the surface of silt and clay loams may be less than the rate of rainfall, so that much of the water runs off the surface either into low spots or into creeks and ditches. Second, the soil already may be saturated. In either of these cases the nitrates will not move down five to six inches as suggested above.

Corn roots usually penetrate to six feet in Illinois soils. Thus, nitrates that leach three to four feet are well within normal rooting depth unless they reach tile lines and are drained from the field.

Nitrification Inhibitors

As Figure 9 shows, nitrification converts ammonium nitrogen into the nitrate form of nitrogen and so increases the potential for soil nitrogen loss. This conversion process can be retarded by using nitrification inhibitors. When inhibitors were properly applied in one experiment, as much as 42 percent of soil-applied ammonia remained in the ammonium form through the early part of the growing season, in contrast to the 4 percent that remained when inhibitors were not used. Inhibitors can therefore have a significant effect on crop yields. However, the success of application will vary with the soil condition, time of year, type of soil, geographic location, rate of nitrogen application, and weather conditions that occur after the nitrogen is applied and before it is absorbed by the crop.

Considerable research throughout the Midwest has shown that inhibitors significantly increase yields only under wet soil conditions. When inhibitors were applied in years of excessive rainfall, corn yield increases ranged from 10 to 30 bushels per acre; when moisture conditions were not as conducive to denitrification or leaching, inhibitors produced no increase.

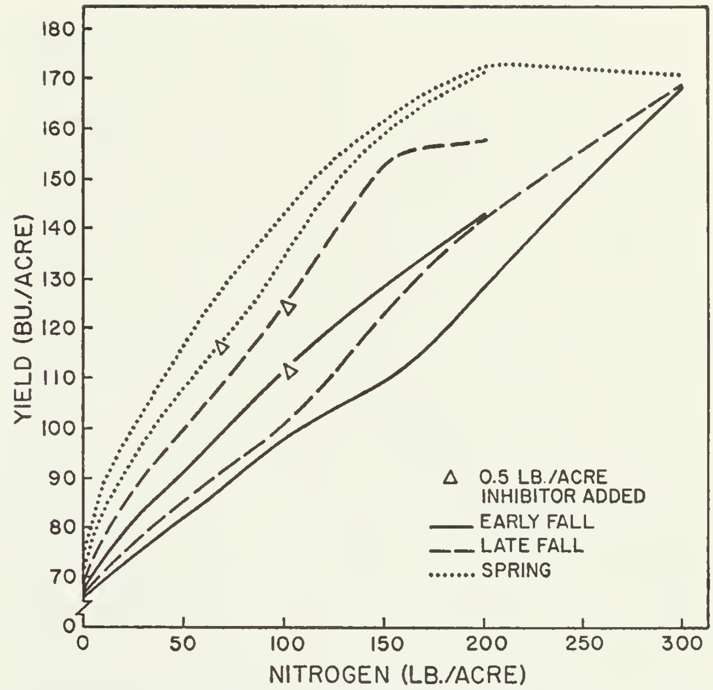
For the first four years of one experiment conducted by the University of Illinois, nitrification inhibitors pro-

duced no effect on grain yields because soil moisture levels were not significantly high. In early May of the fifth year, however, when soils were saturated with water for a long time, the application of an inhibitor in the preceding fall significantly increased corn yields (Fig. 10). Furthermore, at a nitrogen application rate of 150 pounds per acre, the addition of an inhibitor increased grain yields more than the addition of another 40 pounds of nitrogen (Fig. 10). Under the conditions of that experiment, therefore, it was more economical to use an inhibitor than to apply more nitrogen.

The probability of benefit from the use of a nitrification inhibitor with sidedressed nitrogen is less than for their use with either fall- or spring-applied nitrogen because soils do not normally remain saturated with water for very long during the growing season after a sidedressing operation. Moreover, the short time between application and absorption by the crop greatly reduces the potential for nitrogen loss.

The longer the period between nitrogen application and absorption by the crop, the greater the probability that nitrification inhibitors will contribute to higher yields. However, the length of time that fall-applied inhibitors will remain in the soil is partly dependent on soil temperature. On one plot, a Drummer soil that had received an inhibitor application when soil temperatures were 55° F. retained nearly 50 percent of the applied ammonia in ammonium form for approximately 5 months. When soil temperatures were at 70° F., it retained the same amount of ammonia for only 2 months. Fall application of nitrogen with inhibitors should therefore be delayed until soil temperatures reach 60° F. or less, and even though temperatures may decrease to 60° F. in early September, it is advisable to delay applications until the last week in September in northern Illinois and the first week of October in central Illinois.

In general, poorly or imperfectly drained soils will probably benefit the most from nitrification inhibitors. Moderately well drained soils that undergo frequent periods of three or more days of flooding in the spring would also benefit. Coarse-textured soils (sands) are likely to benefit more than finer-textured soils because they have a higher potential for leaching. Time of application and geographic location must be considered along with soil type when determining whether or not to use a nitrification inhibitor. Employing nitrification inhibitors could significantly improve the efficiency of fall-applied nitrogen on the loams, silts, and clays of central and northern Illinois in years when the soil is very wet in the spring. At the same time, presently available inhibitors will not adequately reduce the rate of nitrification in the low organic-matter soils of southern Illinois when nitrogen is applied in the fall for the following year's corn because the lower soil organic-matter content and warmer temperatures of southern Illinois, both in late fall and early spring, will cause the inhibitor to degrade too rapidly. Furthermore, applying an inhibitor on sandy soils in the fall will not adequately reduce



Effect of nitrification inhibitors on corn yields at varying nitrogen application rates. (Fig. 10)

nitrogen loss because the potential for leaching is too high. Therefore, fall applications of nitrogen with inhibitors are not recommended for sandy soils or for soils with low organic-matter content, especially for those soils found south of Interstate Highway 70.

In the spring, preplant applications of inhibitors may be beneficial on nearly all types of soil from which nitrogen loss frequently occurs, especially on sandy soils and southern Illinois soils. Again, inhibitors are more likely to have an effect when subsoils are recharged with water than when subsoils are dry at the beginning of spring.

Nitrification inhibitors are most likely to increase yields when nitrogen is applied at or below the optimum rate. When nitrogen is applied at a rate greater than that required for optimum yields, benefits from an inhibitor are unlikely, even when there is excessive moisture in the soil.

Inhibitors should be viewed as soil management tools that can be used to reduce nitrogen loss. It is not safe to assume, however, that the use of a nitrification inhibitor will make it possible to reduce nitrogen rates below those currently recommended, since those rates were developed with the assumption that no significant amount of nitrogen would be lost.

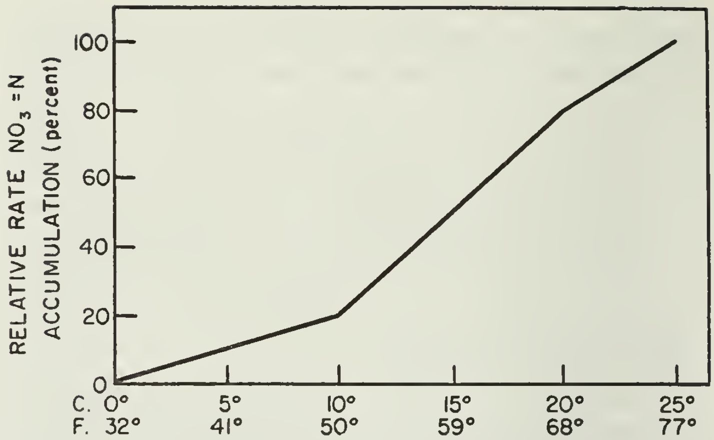
Time of Nitrogen Application

In recent years farmers in central and northern Illinois have been encouraged to apply nitrogen in nonnitrate form in the late fall any time after the soil temperature at four inches was below 50° F., except on sandy, organic, or very poorly drained soils.

The 50° F. level for fall application is believed to be a realistic guideline for farmers. Applying nitrogen earlier

involves risking too much loss (Fig. 11). Later application involves risking wet or frozen fields, which would prevent application and fall plowing. Average dates on which these temperatures are reached are not satisfactory guides because of the great variability from year to year. Soil thermometers should be used to guide fall nitrogen applications.

In Illinois most of the nitrogen applied in late fall or very early spring will be converted to nitrate by corn-planting time. Though the rate of nitrification is slow (Fig. 11), the period of time is long during which the soil temperature is between 32° F. and 40° to 45° F.



Influence of soil temperature on the relative rate of NO_3 accumulation in soils. (Fig. 11)

The results from 18 experiments in central and northern Illinois in four recent years (Fig. 12) show that fall-applied ammonium nitrate (one-half ammonium, one-half nitrate) was less effective than spring-applied nitrogen. There are two ways to compare efficiency. For example, in Figure 12, left, 120 pounds of nitrogen applied in the fall produced 92 percent as much increase as the same amount applied in the spring. But looked at another way, it required 120 pounds of nitrogen to produce as much yield increase in the fall as was produced by 100 pounds in the spring (Fig. 12, right). At higher nitrogen rates, the comparisons become less favorable for fall application because the yield leveled off 6 to 8 bushels below that from spring application.

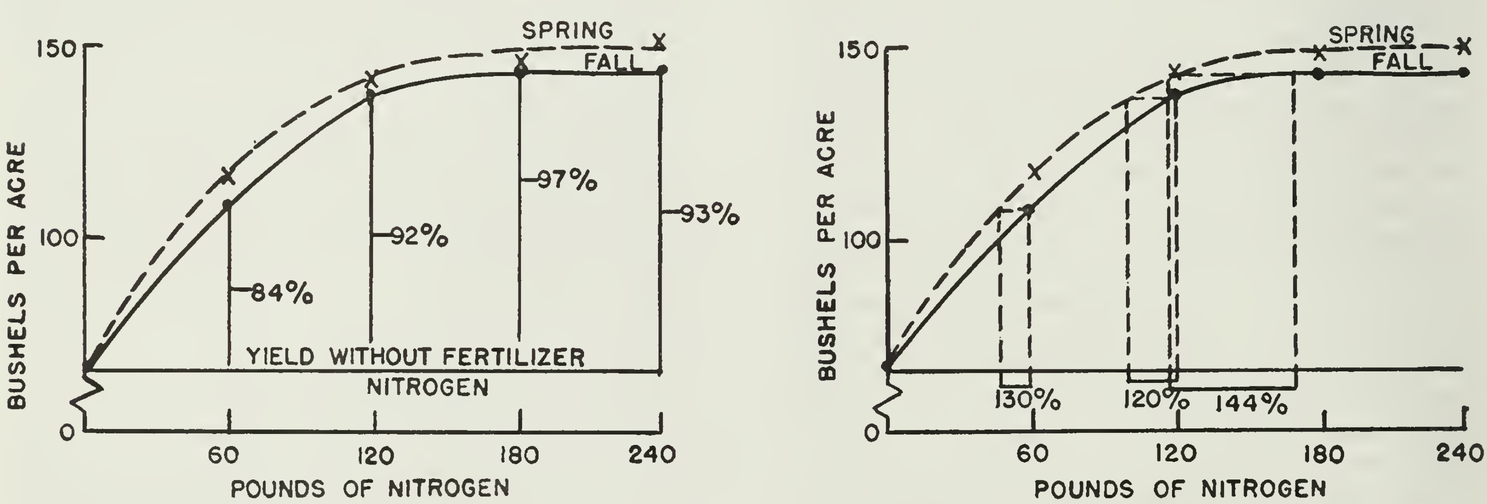
In consideration of the date at which nitrates are formed and the conditions that prevail thereafter, the difference in susceptibility to denitrification and leaching loss between late-fall and early-spring applications of ammonium sources is probably small. Both are, however, more susceptible to loss than is nitrogen applied at planting time or as a sidedressing.

Anhydrous ammonia nitrifies more slowly than other ammonium forms and, therefore, is slightly preferred for fall applications. It is well suited to early spring application, provided the soil is dry enough for good dispersion of ammonia and closure of the applicator slit.

Aerial application. Recent research at the University of Illinois has indicated that an aerial application of dry urea will result in increased yield. This practice should not be considered as a replacement for normal nitrogen application, but rather as an emergency treatment in instances where corn is too tall for normal applicator equipment. Aerial application of nitrogen solutions on growing corn is not recommended, as extensive leaf damage will likely result if the rate of application is greater than 10 pounds of nitrogen per acre.

Which Nitrogen Fertilizer?

The bulk of the nitrogen fertilizer materials available for use in Illinois provides nitrogen in the combined form of ammonia, ammonium, urea, and nitrate. For many uses on a wide variety of soils, all forms are likely to produce about the same yield provided that they are properly applied.



Comparison of fall- and spring-applied ammonium nitrate, 18 experiments in central and northern Illinois, 1966-1969 (DeKalb, Carthage, Carlinville, and Hartsburg). Figure at left shows increased yield from fall fertilizer application as a percent of yield increases achieved when fertilizer was applied in the spring. Figure at right shows amount of fertilizer you need to apply in the fall to obtain a given yield as a percent of the fertilizer needed to obtain that same yield with spring application. (Fig. 12)

Ammonia. Nitrogen materials that contain free ammonia (NH_3), such as anhydrous ammonia or low-pressure solutions, must be injected into the soil in order to avoid gaseous loss of ammonia. Upon injection into the soil, ammonia quickly reacts with water to form ammonium (NH_4^+). In this positively charged form, the ion is not susceptible to gaseous loss because it is temporarily attached to the negative charges on clay and organic matter. Some of the ammonia reacts with organic matter to become a part of the soil humus.

On silt loam or finer textured soils, ammonia will move approximately 4 inches from the point of injection. On coarser textured soils such as sands, ammonia may move 5 to 6 inches from the point of injection. If the depth of application is shallower than the distance of movement, some ammonia may move slowly to the soil surface and escape as a gas over a period of several days. Therefore, on coarse-textured (sandy) soils, anhydrous ammonia should be placed 8 to 10 inches deep, whereas on silt-loam soils, the depth of application should be 6 to 8 inches. Anhydrous ammonia is lost more easily from shallow placement than ammonia in low-pressure solutions. Nevertheless, these low-pressure solutions do contain free ammonia and thus need to be incorporated into the soil at a depth of 2 to 4 inches. Ammonia should not be applied to soils having a physical condition that would prevent closure of the applicator knife track. Ammonia will escape to the atmosphere whenever there is a direct opening from the point of injection to the soil surface.

You can damage seedlings if you do not take proper precautions when applying nitrogen materials that contain or form free ammonia. Damage may occur if you inject nitrogen material into soils that are so wet that the knife track does not close properly. If the soil dries rapidly, this track may open. You can also cause damage by applying nitrogen material to excessively dry soils, which allow the ammonia to move large distances before being absorbed. Finally, you can damage seedlings by using a shallower application than that suggested in the preceding paragraph. Generally, if you delay planting 3 to 5 days after you apply fertilizer, you will see little if any seedling damage. However, under extreme conditions, seedling damage has been observed even when planting was delayed for two weeks after the fertilizer was applied.

Ammonium nitrate. Fifty percent of the nitrogen contained in ammonium nitrate is in the ammonium form and 50 percent is in the nitrate form. That present as ammonium attaches to the negative charges on the clay and organic matter particles and remains in that state until it is utilized by the plant or converted to the nitrate ions by microorganisms present in the soil. Since 50 percent of the nitrogen is present in the nitrate form, this product is more susceptible to loss from leaching and denitrification. Thus, ammonium nitrate should not be applied to sandy soils because of the likelihood of leaching, nor should it be applied far in advance of the time the crop needs the nitrogen because of the possibility of loss by denitrification.

Urea. The chemical formula for urea is $CO(NH_2)_2$. In this form, it is very soluble and moves freely up and down with soil moisture. After being applied to the soil, urea is converted to ammonia either chemically or by the enzyme urease. The speed with which this conversion occurs depends largely on temperature. At low temperatures conversion is slow, but at temperatures of 55° F. or higher conversion is rapid.

If the conversion of urea occurs on the soil surface or on the surface of crop residue or leaves, some of the resulting ammonia will be lost as a gas to the atmosphere. The potential for loss is greatest when:

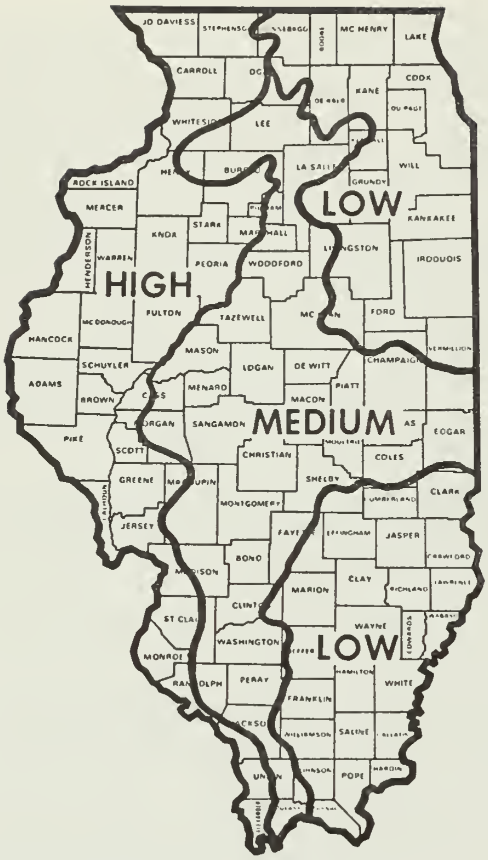
1. Temperatures are greater than 55° F. Loss is less likely with winter or early spring applications.
2. Considerable crop residue remains on the soil surface.
3. Application rates are greater than 100 lbs. N per acre.
4. The soil surface is moist and rapidly drying.
5. Soils have a low cation-exchange capacity.
6. Soils are neutral or alkaline in reaction.

Research conducted at both the Brownstown and Dixon Springs Research Centers have shown that surface application of urea for zero-till corn did not yield as well as ammonium nitrate (Table 44) in most years. In years in which a rain was received within one or two days after application, urea resulted in as good a yield increase as did ammonium nitrate (that is, compared to results from early spring application of ammonium nitrate at Dixon Springs in 1975). In other studies, urea that was incorporated soon after application yielded as well as ammonium nitrate.

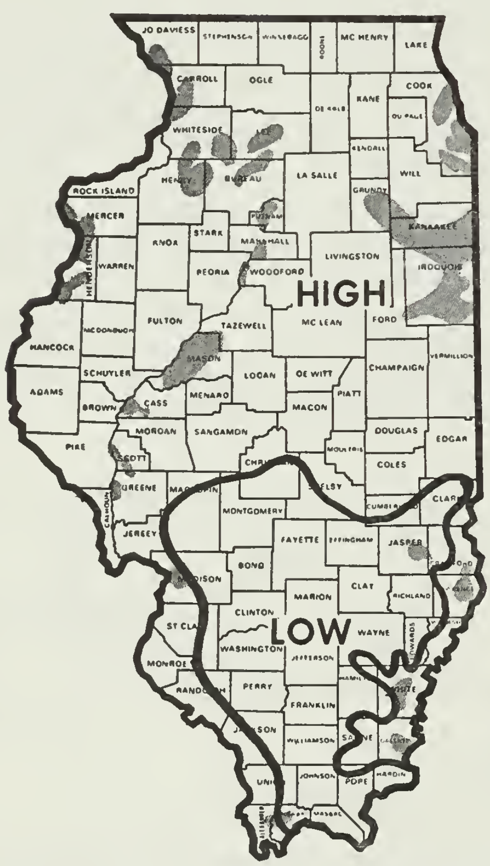
Nitrogen solutions. The non-pressure nitrogen solutions that contain 28 or 32 percent of nitrogen consist of a mixture of urea and ammonium nitrate. Typically, half of the nitrogen is from urea and the other half is from ammonium nitrate. The constituents of these compounds will undergo the same reactions as described above for the constituents applied alone.

Table 44. — Effect of Source of Nitrogen for Zero-Till Corn

Nitrogen: Source	Nitrogen: Date of application	Nitrogen: Method of application	Nitrogen: Rate lbs./acre	Brownstown 1974-77 avg.	Dixon Springs 1974	Dixon Springs 1975
				Yield (bu./acre)		
Control	..	..	0	52	50	
Ammonium nitrate ...	early spring	surface	120	96	132	160
Urea	early spring	surface	120	80	106	166
Ammonium nitrate ...	early June	surface	120	106	151	187
Urea	early June	surface	120	99	125	132



Phosphorus-supplying power. (Fig. 13)



Cation-exchange capacity. The shaded areas are sands with low cation-exchange capacity. (Fig. 14)

Recent experiments at DeKalb have shown a yield difference between incorporated and unincorporated nitrogen solutions which were spring-applied (Table 45). This difference in yield associated with method of application is probably caused by volatilization loss of some nitrogen from the surface-applied solution containing urea.

Phosphorus and Potassium

Inherent Availability

Illinois has been divided into three regions in terms of inherent phosphorus-supplying power of the soil below the plow layer in dominant soil types (Fig. 13).

High phosphorus-supplying power means that the soil test for available phosphorus (P_1 test) is relatively high and conditions are favorable for good root penetration and branching throughout the soil profile.

Low phosphorus-supplying power may be caused by one or more of these factors:

1. A low supply of available phosphorus in the soil profile because (a) the parent material was low in P; (b) phosphorus was lost in the soil-forming process; or (c) the phosphorus is made unavailable by high pH (calcareous) material.
2. Poor internal drainage that restricts root growth.
3. A dense, compact layer that inhibits root penetration or branching.
4. Shallowness to bedrock, sand, or gravel.
5. Drouthiness, strong acidity, or other conditions that restrict crop growth and reduce rooting depth.

Regional differences in phosphorus-supplying power are shown in Figure 13. Parent material and degree of weathering were the primary factors considered in determining the various regions.

The "High" region occurs in western Illinois, where the primary parent material was more than 4 to 5 feet of

Table 45. — Effect of Source and Rate of Spring-Applied Nitrogen on Corn Yield, DeKalb

Carrier	N (lb./acre)	Year 1976	1977	Avg.
		Yield (bu./acre)		
None	0	66	61	64
Ammonia	80	103	138	120
28 pct. N solution incorporated	80	98	132	115
28 pct. N solution unincorporated	80	86	126	106
Ammonia	160	111	164	138
28 pct. N solution incorporated	160	107	157	132
28 pct. N solution unincorporated	160	96	155	126
Ammonia	240	112	164	138
28 pct. N solution incorporated	240	101	164	132
28 pct. N solution unincorporated	240	91	153	122
	FLSD.10	9.1	5.2	

loess that was high in phosphorus content. The soils are leached of carbonates to a depth of more than 3½ feet, and roots can spread easily in the moderately permeable profiles.

The "Medium" region occurs in central Illinois with an arm extending into northern Illinois and a second arm extending into southern Illinois. The primary parent material was more than 3 feet of loess over glacial till, glacial drift, or outwash. Some sandy areas with low phosphorus-supplying power occur in the region. Compared with the high-phosphorus region, more of the soils are poorly drained and have less available phosphorus in the subsoil and substratum horizons. Carbonates are likely to occur at shallower depths than in the "High" region. The soils in the northern and central areas are generally free of root restrictions. Soils in the southern arm are more likely to have root-restricting layers within the profile. Phosphorus-supplying power of soils of the region is likely to vary with natural drainage. Soils with good internal drainage are likely to have high available P levels in the subsoil and substratum. If internal drainage is fair or poor, P levels in the subsoil and substratum are likely to be low or medium.

In the "Low" region in southeastern Illinois, the soils were formed from 2½ to 7 feet of loess over weathered Illinoian till. The profiles are more highly weathered than in the other regions and are slowly or very slowly permeable. Root development is more restricted than in the "High" and "Medium" regions. Subsoil phosphorus levels may be rather high by soil test in some soils of the region, but this is partially offset by conditions that restrict rooting.

In the "Low" region in northeastern Illinois, the soils were formed from thin (less than 3 feet) loess over glacial till. The glacial till, generally low in available phosphorus, ranges in texture from gravelly loam to clay in various soil associations of the region. In addition, shallow carbonates further reduce the phosphorus-supplying power of the soils of the region. High bulk density and slow permeability in the subsoil and substratum restrict rooting in many soils of the region.

The three regions are separated to show broad differences between them. Parent material, degree of weathering, native vegetation, and natural drainage vary within a region and cause variation in phosphorus-supplying power. It appears, for example, that soils developed under forest cover have more available subsoil phosphorus than those developed under grass.

Illinois is divided into two general regions based on cation-exchange capacity (Fig. 14). There are, however, important differences among soils within these general regions because of differences in the seven factors listed below.

1. The amount of clay and organic matter. This influences the exchange capacity of the soil.
2. The degree of weathering of the soil material. This affects the amount of potassium that has been leached out.
3. The kind of clay mineral.
4. Drainage and aeration. These influence K uptake.
5. The amount of calcium and magnesium. Very high calcium and magnesium may reduce K uptake.
6. The parent material from which the soil formed.
7. Compactness or other conditions that influence root growth.

Soils having a cation-exchange capacity less than 12 me./100 g. are classified as having low potassium-supplying power. These include the sandy soils since minerals from which these soils developed are inherently low in K. Sandy soils also have very low cation-exchange capacities and thus do not hold much reserve K.

Silt-loam soils in the "Low" area in southern Illinois (claypans) are relatively older soils in terms of soil development; consequently, much more of the potassium has been leached out of the rooting zone. Furthermore, wetness and a platy structure between the surface and subsoil may interfere with rooting and with K uptake early in the growing period, even though roots are present.

Phosphorus

Rate of Fertilizer Application

Buildup. Certain minimum phosphorus levels are needed in order to produce optimum crop yields.

Near maximum yields of corn and soybeans will be obtained when available phosphorus levels are maintained at 30, 40, and 45 pounds of phosphorus per acre for soils in the high, medium, and low phosphorus-supplying regions, respectively. However, since phosphorus will not be lost from the soil system other than through crop removal or soil erosion and since these are minimum values required for optimum yields, it is recommended that soil-test levels be built up to 40, 45, and 50 pounds per acre for soils in the high, medium, and low phosphorus-supplying regions, respectively. These values ensure that soil phosphorus availability will not limit crop yield.

Research has shown that, as an average for Illinois soils, 9 pounds of P_2O_5 per acre are required to increase the P_1 soil test by 1 pound. Therefore, the recommended rate of buildup phosphorus is equal to nine times the difference between the soil-test goal and the actual soil-test value. The amount of phosphorus recommended for buildup over a four-year period for various soil-test levels is presented in Table 46.

The rate of 9 pounds of P_2O_5 to increase the soil test 1 pound is an average for Illinois soils. As a result, some soils will fail to reach the desired goal in four years with P_2O_5 applied at this rate and others will exceed the goal. Therefore, it is recommended that each field be retested every four years.

In addition to the supplying power of the soil, the optimum soil-test value also is influenced by the crop to be grown. For example, the phosphorus soil-test level

required for optimum wheat and oat yields (Fig. 15) is considerably higher than that required for corn and soybean yields, partly because wheat and corn have different phosphorus uptake patterns. Wheat requires a large amount of readily available phosphorus in the fall, when the root system is feeding primarily from the upper soil surface. Phosphorus is taken up by corn until the grain is fully developed (Fig. 16), so subsoil phosphorus is more important in interpreting the phosphorus test for corn than for wheat. To compensate for the higher phosphorus requirements of wheat and oats, it is suggested that 1.5 times the amount of expected phosphorus removal be applied prior to seeding these crops.

Maintenance. In addition to adding fertilizer to build up the soil test, sufficient fertilizer should be added each year to maintain a specified soil-test level. The amount of fertilizer required to maintain the soil-test value is equal to the amount removed by the harvested portion of the crop (Table 47). The only exception to this is that the maintenance value for wheat and oats is equal to 1.5 times the amount of phosphate (P_2O_5) removed by the grain. This correction has already been accounted for in the maintenance values given in Table 47.

Although it is recommended that soil-test levels be maintained slightly above the level at which optimum yield would be expected, it would not be economical to attempt to maintain the values at excessively high levels. Therefore, it is suggested that no fertilizer be applied if P_1 soil-test values are higher than 60, 65, or 70, respectively, for soils in the high, medium, and low phosphorus-supplying regions.

Potassium

As indicated, phosphorus will usually remain in the soil unless it is removed by a growing crop or by erosion; thus soil levels can be built up as described. Experience in the last several years indicates that on most soils potassium tends to follow the buildup pattern of phosphorus, but on other soils, soil test levels do not buildup as expected. Because of this, both the buildup-maintenance and annual application options are provided.

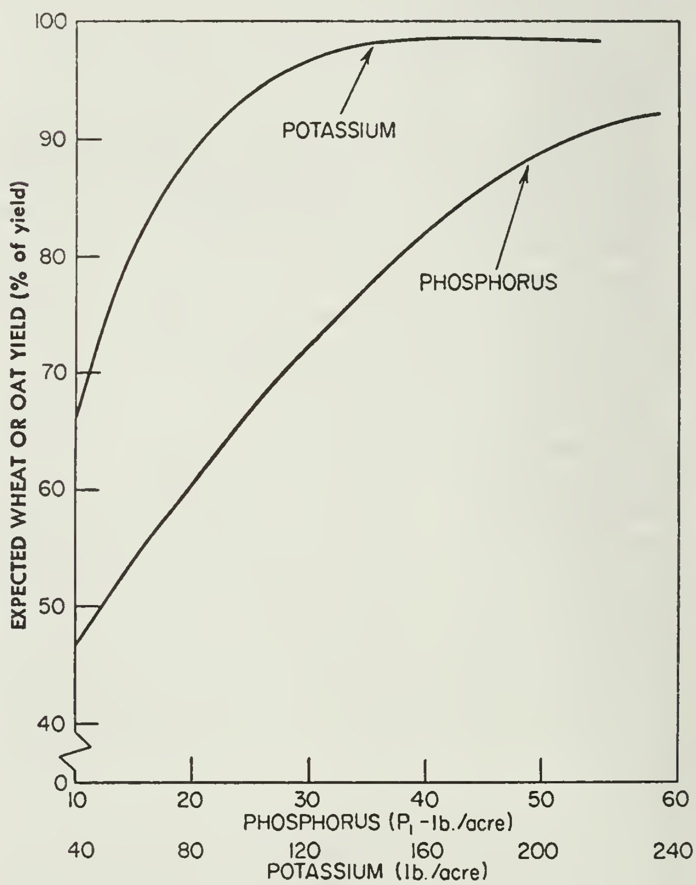
Producers who have one or more of the following conditions should consider the annual application option:

A. Soils where past records indicate that soil test K does not increase when buildup applications are applied.
B. Sandy soils which do not have a large enough capacity to hold adequate amounts of K.
C. Producers who have an unknown or very short tenure arrangement.

On all other fields, use of the buildup-maintenance option is suggested.

Table 46. — Amount of Phosphorus (P_2O_5) Required To Build Up the Soil (based on buildup occurring over a four-year period; 9 pounds of P_2O_5 per acre required to change P_1 soil test 1 pound)

P_1 test (lb./acre)	Pounds of P_2O_5 to apply per acre *each year* for soils with supplying power of: Low	Medium	High
4	103	92	81
6	99	88	76
8	94	83	72
10	90	79	68
12	86	74	63
14	81	70	58
16	76	65	54
18	72	61	50
20	68	56	45
22	63	52	40
24	58	47	36
26	54	43	32
28	50	38	27
30	45	34	22
32	40	29	18
34	36	25	14
36	32	20	9
38	27	16	4
40	22	11	0
42	18	7	0
44	14	2	0
45	11	0	0
46	9	0	0
48	4	0	0
50	0	0	0



Relationship between expected wheat or oat yield and soil-test phosphorus and potassium. (Fig. 15)

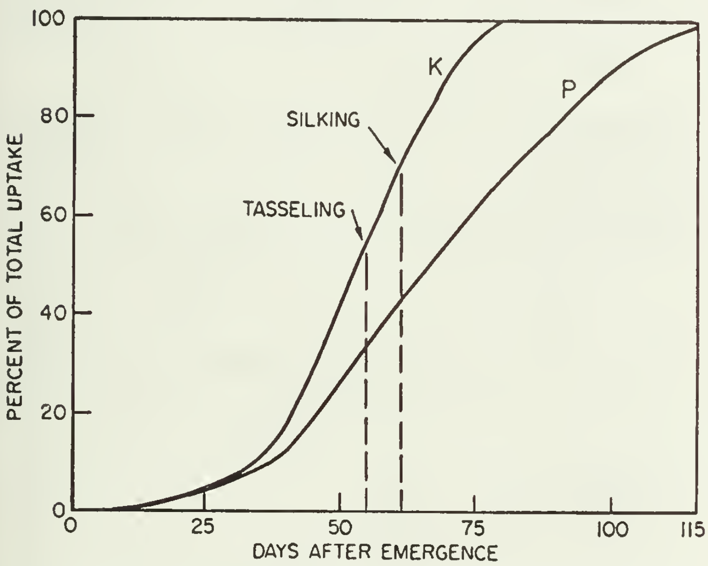
Rate of Fertilizer Application

Buildup maintenance. The only significant loss of soil-applied potassium is through crop removal or soil erosion. Therefore, it is recommended that soil-test potassium be built up to values of 260 and 300 pounds of exchangeable potassium, respectively, for soils in the low- and high-cation-exchange capacity region. These values are slightly higher than that required for maximum yield, but as in the phosphorus recommendations, this will ensure that potassium availability will not limit crop yields.

Research has shown that 4 pounds of K_2O are required, on the average, to increase the soil test 1 pound. Therefore, the recommended rate of potassium application for increasing the soil-test value to the desired goal is equal to four times the difference between the soil-test goal and the actual soil-test value. Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 for dark-colored soils in central Illinois; subtract 45 for light-colored soils in central and northern Illinois; subtract 60 for medium- and light-colored soils in southern Illinois; subtract 45 for fine-textured bottomland soils. Annual potassium application rates recommended for a four-year period for various soil test values are presented in Table 48.

Wheat is not very responsive to potassium unless the soil test is less than 100. However, since wheat is usually grown in rotation with corn and soybeans, it is suggested that soils be maintained at the optimum available potassium level for corn and soybeans.

As with phosphorus, the amount of fertilizer required to maintain the soil test value equals the amount removed by the harvested portion of the crop (Table 47).



Uptake of phosphorus (P) and potassium (K) by corn through the growing season (Hanway, Iowa State University). (Fig. 16)

Table 47. — Maintenance, Fertilizer Required for Various Yields of Crops

Yield (Bu. or tons per acre)	P_2O_5	K_2O[a]
	Pounds per acre	
Corn grain		
90 bu.	39	25
100	43	28
110	47	31
120	52	34
130	56	36
140	60	39
150	64	42
160	69	45
170	73	48
180	77	50
190	82	53
200	86	56
Oats		
50 bu.	19	10
60	23	12
70	27	14
80	30	16
90	34	18
100	38	20
110	42	22
120	46	24
130	49	26
140	53	28
150	57	30
Soybeans		
30 bu.	26	39
40	34	52
50	42	65
60	51	78
70	60	91
80	68	104
90	76	117
100	85	130
Corn silage		
90 bu.; 18T	48	126
100; 20	53	140
110; 22	58	154
120; 24	64	168
130; 26	69	182
140; 28	74	196
150; 30	80	210
Wheat		
30 bu.	27	9
40	36	12
50	45	15
60	54	18
70	63	21
80	72	24
90	81	27
100	90	30
110	99	33
Alfalfa, grass, or alfalfa-grass mixtures		
2T	24	100
3	36	150
4	48	200
5	60	250
6	72	300
7	84	350
8	96	400
9	108	450
10	120	500

[a] If the annual application option is chosen, then K application would be 1.5 times the values shown below.

Potassium fertilizer need not be applied if available K is higher than 360 and 400, respectively, for soils in the low- and high-cation-exchange-capacity regions, unless crops that remove large amounts of potassium (such as alfalfa or corn silage) are being grown. When soils test between 400 and 600 pounds per acre of K, and alfalfa or corn silage is being grown, the soil should be tested every two years instead of four, or maintenance levels of potassium should be added to ensure that soil test levels do not go below the point of optimum yields.

Annual Application Option. If soil test levels are below the desired buildup goal, apply potassium fertilizer annually at an amount equivalent to 1.5 times the potassium content in the harvested portion of the expected yield. If levels are only slightly below desired buildup levels so that buildup and maintenance are less than 1.5 times removal, add the lesser amount. Continue to monitor the soil test K level every four years.

If soil test levels are within a range from the desired goal to 100 pounds above the desired potassium goal, apply enough potassium fertilizer to replace what the harvested yield will remove.

Each of the proposed options (buildup maintenance and annual) have advantages and disadvantages. In the short run, the annual option will likely be less costly. In the long run, the buildup approach may be more economical. In years of high income, tax benefits may be obtained by applying high rates of fertilizer. Also, in periods of low fertilizer prices, the soil can be built to higher levels which in essence bank the materials in the soil for use at a later date when the economy may not be as good for fertilizer purchases. Producers using the buildup system are insured against yield loss that might occur in years when weather conditions prevent fertilizer application, or in years when fertilizer supplies are not adequate. The primary advantage of the buildup concept is that it has a slightly lower risk of potential yield reduction that might result from lower annual fertilizer rates. This is especially true in years of exceptionally favorable growing conditions. The primary disadvantage of the buildup option is high fertilizer cost in the initial buildup years.

Examples of how to figure phosphorus and potassium fertilizer recommendations are presented as follows.

Table 48. — Amount of Potassium (K_2O) Required To Build Up the Soil (based on the buildup occurring over a four-year period; 4 pounds of K_2O per acre required to change the K test 1 pound)

K test[a] (lb./acre)	Amount of K_2O to apply per acre *each year* for soils with cation exchange capacity: Low[b]	High[b]
50	210	250
60	200	240
70	190	230
80	180	220
90	170	210
100	160	200
110	150	190
120	140	180
130	130	170
140	120	160
150	110	150
160	100	140
170	90	130
180	80	120
190	70	110
200	60	100
210	50	90
220	40	80
230	30	70
240	20	60
250	10	50
260	0	40
270	0	30
280	0	20
290	0	10
300	0	0

[a] Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 pounds for dark-colored soils in central Illinois; 45 pounds for light-colored soils in central and northern Illinois, and fine-textured bottomland soils; and 60 pounds for medium- and light-colored soils in southern Illinois.

[b] Low cation-exchange-capacity soils would be those with CEC less than 12 me./100 g. soil, and high would be those equal to or greater than 12 me./100 g. soil.

Example 1. Continuous corn with a yield goal of 140 bushels per acre:

(a) *Soil-test results*

Soil-test results	Soil region
P_1 30	high
K 250	high

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	22 (Table 46)	50 (Table 48)
Maintenance	60 (Table 47)	39 (Table 47)
Total	82	89

Example 2. Corn-soybean rotation with a yield goal of 140 bushels per acre for corn and 40 bushels per acre for soybeans:

(a) *Soil-test results*

Soil-test results	Soil region
P_1 20	low
K 200	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Corn		
Buildup	68	60
Maintenance	60	39
Total	128	99
Soybeans		
Buildup	68	60
Maintenance	34	52
Total	102	112

Note that buildup recommendations are independent of the crop to be grown, but maintenance recommendations are directly related to the crop to be grown and the yield goal for the particular crop.

Example 3. Continuous corn with a yield goal of 150 bushels per acre:

(a) *Soil-test results*

Soil-test results	Soil region
P_1 90	low
K 420	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	0	0
Maintenance	0	0
Total	0	0

Note that soil-test values are higher than those suggested; thus, no fertilizer would be recommended. Retest the soil after four years to determine fertility needs.

Example 4. Corn-soybean rotation with a yield goal of 120 bushels per acre for corn and 35 bushels per acre for soybeans:

(a) *Soil-test results*

Soil-test results	Soil region
P_1 20	low
K 180	low (soil test does not increase as expected)

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Corn		
Buildup	68	—
Maintenance	52	
Total	120	51 (34 x 1.5)
Soybeans		
Buildup	68	—
Maintenance	30	—
Total	98	69 (46 x 1.5)

For farmers planning to double crop soybeans after wheat, it is suggested that phosphorus and potassium fertilizer required for both the wheat and soybeans be applied prior to seeding the wheat. This practice will reduce the number of field operations necessary at planting time and will hasten the planting operation.

The maintenance recommendations for phosphorus and potassium in a double-crop wheat and soybean system are presented in Tables 49 and 50, respectively. Assuming a wheat yield of 50 bushels per acre followed by a soybean yield of 30 bushels per acre, the maintenance recommendation would be 71 pounds of P_2O_5 and 54 pounds of K_2O per acre.

Time of Application

Although the fertilizer rates for buildup and maintenance in Tables 46 through 48 are for an annual application, producers may apply enough nutrients in any one year to meet the needs of the crops to be grown in the succeeding two- to three-year period.

For perennial forage crops, broadcast and incorporate all of the buildup and as much of the maintenance phosphorus as economically feasible prior to seeding. On low-fertility soils, apply 30 pounds of phosphate (P_2O_5) per acre using a band seeder. If a band seeder is used, you may safely apply a maximum of 30 to 40 pounds of potash (K_2O) per acre in the band with the phosphorus. Up to 600 pounds of K_2O per acre can be safely broadcast in the seedbed without damaging seedlings.

Topdress applications of phosphorus and potassium on perennial forage crops may be applied at any convenient time. Usually this will be after the first harvest or in September.

High Water Solubility of Phosphorus

The water solubility of the P_2O_5 listed as available on the fertilizer label is of little importance under typical field crop and soil conditions on soils with medium to high levels of available phosphorus, when recommended rates of application and broadcast placement are used.

There are some exceptions when water solubility is important. These include the following:

1. For band placement of a small amount of fertilizer to stimulate early growth, at least 40 percent of the phosphorus should be water soluble for application to acid soils and preferably 80 percent for calcareous soils. As shown in Table 51, the phosphorus in nearly all fertilizers commonly sold in Illinois is highly water soluble. Phosphate water-solubility in excess of 75 to 80 percent has

Table 49. — Maintenance Phosphorus Required for Wheat-Soybean Double-Crop System

Wheat yield (bu./acre)	Soybean yield (bu./acre) 20	30	40	50	60
	P_2O_5 (lb./acre)				
30	44	53	61	69	78
40	53	62	70	78	87
50	62	71	79	87	96
60	71	80	88	96	105
70	80	89	97	105	114
80	89	98	106	114	123

Table 50. — Maintenance Potassium Required for Wheat-Soybean Double-Crop System

Wheat yield (bu./acre)	Soybean yield (bu./acre) 20	30	40	50	60
	K_2O (lb./acre)				
30	35	48	61	74	87
40	38	51	64	77	90
50	41	54	67	80	93
60	44	57	70	83	96
70	47	60	73	86	99
80	50	63	76	89	102

not been shown to give further yield increases above those that have water-solubility levels of 50 to 80 percent.

2. For calcareous soils, a high degree of water solubility is desirable, especially on soils that are shown by soil test to be low in available phosphorus.

Secondary Nutrients

The elements that are classified as secondary nutrients include calcium, magnesium, and sulfur. Deficiency of calcium has not been recognized in Illinois where soil pH is 5.5 or above. Calcium deficiency associated with acid soils should be corrected by the use of limestone adequate to correct the soil pH.

Magnesium deficiency has been recognized in isolated situations in Illinois. Although the deficiency is usually associated with acid soils, there have been instances of low magnesium reported on sandy soils where the soils were not excessively acid. The soils most likely to be deficient in magnesium include sandy soils throughout Illinois and low-exchange capacity soils of southern Illinois. Deficiency will be more likely where calcitic rather than dolomitic limestone has been used and where potassium test levels have been high (above 400). Suggested soil test magnesium levels are 60-75 pounds per acre on sandy soils and 120-150 pounds per acre on silt loam or finer textured soils for grain crops.

Recognition of sulfur deficiency has been reported with increasing frequency throughout the Midwest. These deficiencies probably are occurring because of (1) increased use of S-free fertilizer, (2) decreased use of sulfur as a fungicide and insecticide, (3) increased crop yields, resulting in increased requirements for all of the essential plant nutrients, and (4) decreased atmospheric sulfur supply.

Organic matter is the primary source of sulfur in soils. Thus soils low in organic matter are more likely to be deficient than are soils with a high level of organic matter. Since sulfur is very mobile and can be readily leached, deficiency is more likely to be found on sandy soils than on finer textured soils.

A statistically significant yield response to sulfur application was observed at 5 out of 87 locations in Illinois (Table 52). Two of these responding sites, one an eroded silt loam and one a sandy soil, were found in northwestern Illinois (Whiteside and Lee Counties); one site, a silty clay loam, was found in central Illinois (Sangamon County); and two sites, one a silt loam and one a sandy loam soil, were found in southern Illinois (Richland and White Counties).

At the responding sites, sulfur treatments resulted in corn yields that averaged 11.2 bushels per acre more than yields from the untreated plots. At the nonresponding sites, yields from the sulfur-treated plots averaged only 0.5 bushel per acre more than those from the untreated plots (Table 52). If one considers only the responding sites, the sulfur soil test predicts with good reliability which sites will respond to sulfur applications. Of the 5 responding sites, 1 had only 12 pounds of sulfur per acre, less than the amount considered necessary for normal plant growth, and 3 had marginal sulfur concentration (from 12 to 20 pounds of sulfur per acre). Sulfur tests on the 80 nonresponding sites showed 14 to be deficient and 29 to have a level of sulfur that is considered marginal for normal plant growth. However, sulfur applications produced no significant positive response in these plots. The correlation between yield increases and measured sulfur soil levels was very low, indicating that the sulfur soil test did not reliably predict sulfur need.

In addition to soil test values, one should also consider organic matter level, potential atmospheric sulfur contributions, subsoil sulfur content, and moisture conditions just prior to soil sampling in determining whether a sulfur response is likely. If organic matter levels are greater than 2.5 percent, use sulfur on a trial basis even when the soil test reading is low. If the field in question is located in an area downwind from industrial operations where significant amounts of sulfur are being emitted, use sulfur on a trial basis even when the soil test reading is low. Since sulfur is a mobile nutrient supplied principally by organic matter oxidation, abnormal precipitation (either high or low) could adversely affect the sulfur status of samples taken from the soil surface. If precipitation has been high just prior to sampling, some samples may have a low reading due to leaching. If precipitation were low and temperatures warm, some soils may have a high reading when in fact the soil is not

Table 51. — Characteristics of Some Common Processed Phosphate Materials

Material	Pct. P_2O_5	Pct. water soluble	Pct. citrate soluble	Total pct. available
Ordinary superphosphate 0-20-0	16–22	78	18	96
Triple superphosphate	44–47	84	13	97
Mono-ammonium phosphate 11-48-0	46–48	100	..	100
Diammonium phosphate 18-46-0	46	100	..	100
Ammonium polyphosphate 10-34-0 11-37-0	34–37	100	..	100

Table 52. — Average Yields at Responding and Nonresponding Zinc and Sulfur Test Sites, 1977–79

	Number of sites	Yield from untreated plots	Yield from zinc-treated plots	Yield from sulfur-treated plots
		Bushels per acre		
Responding sites				
Low-sulfur soil	5	140.0	....	151.2
Low-zinc soil	3	150.6	164.7	....
Nonresponding sites ..	80	147.6	146.2	148.2

capable of supplying adequate amounts of sulfur throughout the growing season.

Micronutrients

The elements that are classified as essential micronutrients include zinc, iron, manganese, copper, boron, molybdenum, and chlorine. These nutrients are classified as micronutrients because they are required in small (micro) amounts. Confirmed deficiences of these micronutrients in Illinois have been limited to boron deficiency of alfalfa, zinc deficiency of corn, and iron and manganese deficiency of soybeans.

Manganese deficiency (stunted plants with green veins in yellow or whitish leaves) is common on high-pH (alkaline), sandy soils, especially during cool, wet weather in late May and June. Suggested treatment is to spray 10 pounds of manganese sulfate (containing 2.5 pounds of manganese) per acre in 25 gallons of water when the beans are 6 to 10 inches tall. If the spray is directed on the row, the rate can be cut in half. Some fertilizer dealers have other manganese formulations that you can apply according to instructions. Broadcast application on the soil is ineffective because the manganese becomes unavailable in soils with a high pH.

Wayne and Hark soybean varieties often show iron deficiency on soils with a very high pH (usually 7.4 to 8.0). The symptoms are similar to manganese deficiency. Most of the observed deficiencies have been on Harpster, a "shelly" soil that occurs in low spots in some fields in central and northern Illinois. This problem has appeared on Illinois farms only since the Wayne variety was introduced in 1964.

Soybeans often outgrow the stunted, yellow appearance of iron shortage. As a result, it has been difficult to measure yield losses or decide whether or how to treat affected areas. Sampling by U.S. Department of Agriculture scientists in 1967 indicated yield reductions of 30 to 50 percent in the center of severely affected spots. The yield loss may have been caused by other soil factors associated with a very high pH and poor drainage, rather than by iron deficiency itself. Several iron treatments were ineffective in trials near Champaign and DeKalb in 1968.

Recent research in Minnesota has shown that time of iron application is critical if an effective control is to be attained. Researchers recommend that a rate of 0.15 pound iron per acre as iron chelate be applied to leaves within 3 to 7 days after chlorosis symptoms develop (usually in the second trifoliate stage of growth). Waiting for soybeans to grow to the fourth or fifth trifoliate stage before applying iron did not result in a yield increase. Because iron applied to the soil surface between rows does not help, directed applications directly over the soybean plants are preferred.

A significant yield response to zinc applications was observed at 3 out of 85 sites evaluated in Illinois (Table 52). The use of zinc at the responding sites produced a corn yield that averaged 14.1 bushels per acre more than in the check plots. Two sites were Fayette silt loams in Whiteside County, and one was a Greenriver sand in Lee County.

At two of the three responding sites, tests showed that the soil was low or marginal in available zinc. The soil of the third had a very high zinc level but was deficient in available zinc, probably because of the excessively high phosphorus level also found at that site.

The soil-test procedures accurately predicted results for two-thirds of the responding sites. However, the same tests incorrectly predicted that 19 other sites would respond. These results suggest that the soil test for available zinc can indicate where zinc deficiencies are found but does not indicate reliably whether the addition of zinc will increase yields.

In order to identify areas before micronutrient deficiencies become important, we need to continually observe the most sensitive crops in soil situations in which the elements are most likely to be deficient (Table 53).

In general, deficiencies of most micronutrients are accentuated by one of five situations: (1) strongly weathered soils, (2) coarse-textured soils, (3) soils high in pH, (4) organic soils, and (5) soils inherently low in organic matter or low in organic matter because of removal of topsoil by erosion or land-shaping processes.

The use of micronutrient fertilizers should be limited to the application of specific micronutrients to areas of known deficiency. Only the deficient nutrient should be applied. An exception to this would be when farmers already in the highest yield bracket try micronutrients on an experimental basis in fields that are yielding less than would be expected under good management, which includes an adequate nitrogen, phosphorus, and potassium fertility program and a favorable pH.

Method of Fertilizer Application

With the advent of new equipment, producers have a number of options for placement of fertilizers. These options range from traditional broadcast application to injection of the materials at varying depths in the soil. Selection of the proper application technique for a particular field will depend at least in part on the inherent fertility level, the crop to be grown, the land tenure, and the tillage system.

On fields where the fertility level is at or above the desired goal, there is little research evidence to show any significant difference in yield that is associated with method of application. However, on low testing soils and in soils that "fix" phosphorus, placement of the fertilizer within a concentrated band has been shown to result in higher yields. This is particularly true at low rates of application. On higher testing soils, plant recovery of applied fertilizer in the year of application will usually be greater from a band than a broadcast application, although yield differences are unlikely.

Broadcast fertilization. On highly fertile soils, both maintenance and buildup phosphorus and potassium will

be efficiently utilized when broadcast and plowed or disked in. This system, particularly when the tillage system includes a moldboard plow every few years, creates a uniform distribution of nutrients throughout the entire plow depth. As a result, roots growing within that zone have access to high levels of fertility. Since the nutrients are intimately mixed with a large volume of soil, there would be opportunity for increased nutrient fixation on soils having a high fixation ability. Fortunately, most Illinois soils do not have high phosphorus or potassium fixation rates.

Row fertilization. On low fertility soils, placement of the fertilizer in a concentrated band below and to the side of the seed has been shown to be an efficient method of application. This is especially true in those situations where the rate of application is markedly less than that needed to build the soil to the desired level. Producers who are not assured of having a long-term tenure on the land may wish to consider this option. The major disadvantages of this technique are: (1) additional time and labor requirement at planting time, (2) limited root fertilizer contact, and (3) inadequate rate of application to increase soil levels for future crops.

Strip application. This technique consists of applying phosphorus and/or potassium in narrow bands on approximately 30-inch centers on the soil surface, in the same direction as the primary tillage. The theory behind this technique is that, after moldboard plowing, the fertilizer will be distributed in a narrow vertical band throughout the plow zone. Use of this system reduces the amount of soil-to-fertilizer contact as compared with a broadcast application, and thus it reduces the potential for nutrient fixation. Since the fertilizer is distributed through more soil volume than with a band application, there will be more opportunity for root fertilizer contact.

Deep fertilizer placement. Several terms have been used to define this technique. They include root zone banding, dual placement, knife injection, and deep placement. This system refers to the injection of an N-P or N-P-K mixture at a depth ranging from 4 to 8 inches. The knife spacings used may vary by crop to be grown, but generally they are 15 to 18 inches apart for close-grown crops such as wheat and 30 inches for row crops. Use of this technique provided a significantly higher wheat yield as compared with a broadcast application of the same rate of nutrients in some, but not all, experiments conducted in Kansas. Wisconsin research showed this technique to be equivalent to that of a band application for corn on a soil testing high in phosphorus but inferior to that of a band application for corn on a low-testing soil. If this system is used on low-testing soils, it would be advisable to apply a portion of the phosphorus fertilizer in a band with the planter.

Dribble fertilization. This technique involves the application of urea-ammonium nitrate solutions in concentrated bands on 30-inch spacings on the soil surface. Results from several states have shown that this system reduces the potential for nitrogen loss of these materials as compared with an unincorporated broadcast application. However, it has not been shown to be superior to an injected or an incorporated application of urea-ammonium nitrate solution.

"Pop-up" fertilization. The term "pop-up" is a misnomer. The corn does not emerge sooner than it does without this kind of application, and it may come up 1 or 2 days later. The corn may, however, grow more rapidly during the first 1 to 2 weeks after emergence.

Table 53. — Soil Situations and Crops Susceptible to Micronutrient Deficiency

Micronutrient	Sensitive crop	Susceptible soil situations	Season favoring deficiency
Zinc (Zn)	Young corn	1. Low organic matter either inherent or because of erosion or land shaping 2. High pH, i.e. >7.3 3. Very high phosphorus 4. Restricted root zone 5. Coarse textured (sandy) 6. Organic soils	Cool, wet
Iron (Fe)	Wayne soybeans, grain sorghum	1. High pH	Cool, wet
Manganese (Mn)	Soybeans, oats	1. High pH 2. Restricted root zone 3. Organic soils	Cool, wet
Boron (B)	Alfalfa	1. Low organic matter 2. High pH 3. Strongly weathered soils in south-central Illinois 4. Coarse textured (sandy)	Drought
Copper (Cu)	Corn	1. Infertile sand 2. Organic soils	Unknown
Molybdenum (Mo)	Soybeans	1. Strongly weathered soils in south-central Illinois	Unknown
Chlorine (Cl)	Unknown	1. Coarse-textured soils	Excessive leaching by low Cl water

"Pop-up" fertilizer will make corn look very good early in the season and may aid in early cultivation for weed control. But there is not likely to be a substantial difference in yield produced in most years by a "pop-up" application or by fertilizer that is placed in a band to the side and below the seed. With these two placements there seldom will be a difference of more than a few days in the time the root system intercepts the fertilizer band.

"Pop-up" fertilization means placing 40 to 50 pounds of fertilizer per acre in contact with the seed. Research in many states over a long period of time has shown that, for starter effect only, you should place fertilizer as close to the seed as safety permits. The tube from the fertilizer hopper is positioned to do this; the fertilizer is not mixed with the seed prior to planting.

"Pop-up" fertilizer should contain all three major nutrients in a ratio of about 1-4-2 of N-P_2O_5-K_2O (1-1.7-1.7 of N-P-K). The maximum safe amount of $N + K_2O$ for "pop-up" placement is about 10 to 12 pounds per acre in 40-inch rows and correspondingly more in 30- and 20-inch rows. It is, in fact, necessary to apply more in narrow rows to have an equal amount per foot of row.

"Pop-up" fertilizer is unsafe for soybeans. In research conducted at Dixon Springs by George McKibben, a stand was reduced to one-half by applying 50 pounds of 7-28-14 and to one-fifth with 100 pounds of 7-28-14.

Foliar fertilization. Researchers have known for many years that plant leaves absorb and utilize nutrients sprayed on them. Foliar fertilization has been successfully used for certain crops and nutrients. This method of application has had the greatest use with nutrients required in only small amounts by plants. Nutrients required in large amounts, such as nitrogen, phosphorus, and potassium, have usually been applied to soil rather than to foliage.

The possible benefit of foliarly applied nitrogen fertilizer was researched at the University of Illinois in the 1950's. Foliarly applied nitrogen increased corn and wheat yield, provided that the soil was deficient in nitrogen. Where adequate nitrogen was applied to the soil, additional yield increases were not obtained from foliar fertilization.

Additional research in Illinois was conducted on foliar application of nitrogen to soybeans in the 1960's. This effort was an attempt to supply additional nitrogen to soybeans without decreasing nitrogen symbiotically fixed. That is, it was thought that if nitrogen application was delayed until after nodules were well established, then perhaps symbiotic fixation would remain active. Single or multiple applications of nitrogen solution to foliage did not increase soybean yields. Damage to vegetation occurred in some cases because of leaf "burn" caused by the nitrogen fertilizer.

Although considerable foliar fertilization research had been conducted earlier in Illinois, new research was conducted in 1976 and 1977. This new research was prompted by a report from a neighboring state which indicated that soybean yields had recently been increased by as much as 20 bushels per acre in some trials. Research in that state differed from our earlier work on soybeans in that, in addition to nitrogen, the foliar fertilizer increased yield only if phosphorus, potassium, and sulfur were also included. Researchers there thought that soybean leaves became deficient in nutrients as nutrients were translocated from vegetative parts to the grain during grain development. They reasoned that foliar fertilization, which would prevent leaf deficiencies, should result in increased photosynthesis that would be expressed in higher grain yields.

Foliar fertilization was conducted at several locations in Illinois during 1976 and 1977 — ranging from Dixon Springs in southern Illinois to DeKalb in northern Illinois. None of the experiments gave economical yield increases. In some cases there were yield reductions, which were attributed to leaf damage caused by the fertilizer. Table 54 contains data from a study at Urbana where soybeans were sprayed four times with various fertilizer solutions. Yields were not increased by foliar fertilization.

Nontraditional Products

It seems hard to believe that in this day of better informed farmers the number of letters, calls, and promotional leaflets about nontraditional products is increasing. The claim is usually that Product X either replaces fertilizers and costs less, makes nutrients in the soil more available, supplies micronutrients, or is a natural product that does not contain strong acids that kill soil bacteria and earthworms.

The strongest position that legitimate fertilizer dealers, extension advisers, and agronomists can take is to challenge these peddlers to produce unbiased research results to support their claims. Farmer testimonials are no substitute for research.

Extension specialists at the University of Illinois are ready to give unbiased advice when asked about purchasing new products or accepting a sales agency for them.

In addition, each county extension office has the publication "Compendium of Research Reports on the Use of Nontraditional Materials for Crop Production," which contains data on a number of nontraditional products that have been tested in the Midwest. Check with your local extension office for this information.

Table 54. — Yields of Corsoy and Amsoy Soybeans After Fertilizer Treatments Were Sprayed to the Foliage Four Times, Urbana

Treatment per spraying, lb./acre				Yield, bu./acre	
N	P_2O_5	K_2O	S	Corsoy	Amsoy
0	0	0	0	61	56
20	0	0	0	54	53
0	5	8	1	58	56
10	5	8	1	56	58
20	5	8	1	55	52
30	7.5	12	1.5	52	46

SOIL MANAGEMENT AND TILLAGE SYSTEMS

Intensive use of a moldboard plow, disk, harrow, and cultivator was once the only practical tillage system that could give the crop producer reasonable assurance of establishing a crop and controlling weeds. Modern herbicides and implements have made alternatives to the traditional intensive tillage system possible. When choosing a tillage system, one should consider crop yields, costs, and soil erosion. With these areas in mind, one must evaluate the tillage method as it relates to soil type, slope, drainage, and temperature, timeliness, and fertilizer distribution, and each method's potential for weed, insect, and disease control.

The following four sections describe tillage systems used in Illinois and list some advantages and disadvantages of each.

Moldboard Plow System

(Conventional Clean Tillage)

Primary tillage is done with a moldboard plow. Secondary tillage includes one or more operations with a disk, field cultivator, harrow, or similar implement.

Advantages

1. The uniform fine seedbed gives good seed-soil contact and easy planting.
2. Insecticides and herbicides are most effective in a uniform, fine seedbed that is free of crop residues.
3. Survival of some insects, especially European corn borer, is reduced because corn stalk residues are buried.
4. The system is flexible and adaptable to a wide range of soil and crop conditions.
5. Use of labor and machinery is reasonably well distributed with fall plowing.
6. Yields are as high as or higher than with alternative tillage systems over a wide range of soil and weather conditions.
7. A wide selection of herbicides can be used, and their performance is usually better than with alternative tillage systems.

Disadvantages

1. Bare soil is very susceptible to wind and water erosion.
2. Soil crusting is often a problem with a uniform fine seedbed.
3. Fuel consumption and machinery costs are high.

Chisel Plow System

Primary tillage is done with a chisel plow, usually in the fall, followed by use of a disk or field cultivator in the spring.

Advantages

1. Machinery costs are slightly lower than with moldboard plowing due to lower energy requirements per acre.
2. The soil surface is rough and partially covered by crop residues that reduce raindrop impact and runoff, resulting in more water infiltration and less soil erosion.
3. Soil roughness and residues protect the soil from wind erosion.
4. Less time is required for primary tillage compared to that for moldboard plowing.
5. Yields are comparable to other tillage systems, especially on well-drained soils. On poorly drained soils, the chisel plow system can be used for at least three or four years before moldboard plowing without any significant yield decrease.

Disadvantages

1. In heavy residue, a heavy planter with disk openers and a coulter in front of each row may be needed for planting.
2. Soil temperatures are lower, especially on poorly drained soils, resulting in slightly slower early corn growth in the northern two-thirds of Illinois.
3. Stands are sometimes slightly lower than with conventional tillage.
4. A tractor must be available with adequate horsepower to pull a chisel plow.
5. Slightly higher herbicide rates may be required to give satisfactory weed control.
6. Crop residues on the soil surface may harbor insects and disease-causing organisms.
7. Erosion control may be lost in the spring if excessive spring tillage is used.

Disk System

A heavy disk or a tandem disk harrow is used for primary tillage in the fall or spring. A field cultivator or a light disk is used for secondary tillage. Advantages and disadvantages of the chisel plow system apply to the disk system, provided that the disk is set to produce a rough soil surface covered with some crop residues.

No-Tillage System (Zero-Tillage)

Seed is planted in previously undisturbed soil by means of a special heavy planter equipped to plant through residue in firm soil. Fertilizers and pesticides must be applied to the soil surface or in the narrow, tilled area of the row. Weeds growing at planting are killed with a contact herbicide.

Advantages

1. Soil erosion is greatly reduced compared to that from other systems.
2. Power, labor, and fuel costs are greatly reduced compared to those resulting from other tillage systems.
3. The planter can be used in crop residues, sod, or in a conventionally tilled seedbed.
4. Plant residues on the soil surface reduce evaporation.

Disadvantages

1. Low soil temperatures often delay emergence and cause slow early growth.

2. A special planter or planter attachments may be needed. Special care should be exercised when planting to ensure adequate seed-soil contact, a uniform planting depth, and a uniform seed cover.

3. Rodents and birds may reduce stands.

4. Some insect and crop disease problems may be enhanced when crop residues are left on the soil surface.

5. Without cultivation, weed control is entirely dependent on herbicides.

6. Higher herbicide rates or more costly herbicide combinations are usually needed for adequate weed control.

Soil Erosion and Tillage

Bare, smooth soil left by moldboard plowing and intensive secondary tillage is extremely susceptible to soil erosion. Many Illinois soils have subsurface layers that are unfavorable for root development. Soil erosion slowly but permanently removes the soil that is most favorable for crop growth, resulting in gradually decreasing soil productivity and value. Even on soils without root-restricting subsoils, erosion removes nutrients that must be replaced with additional fertilizer to maintain yields.

Sediment from eroding fields increases water pollution, reduces the storage capacity of lakes and reservoirs, and decreases the efficiency of drainage systems.

Effective erosion control systems usually include one or more of three features: (1) the soil is protected with a cover of vegetation, such as a mulch of crop residue; (2) the soil is tilled so that a maximum amount of water is absorbed with a minimum of runoff; (3) long slopes are divided into a series of short slopes so that the water cannot get "running room."

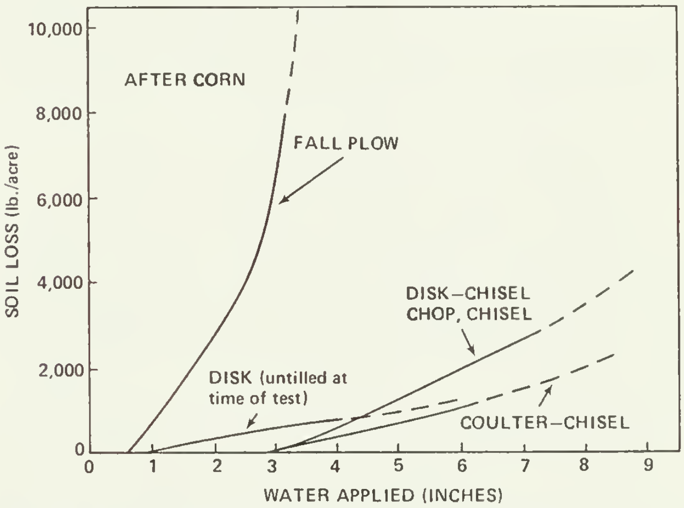
Chisel plow, no-tillage, and other tillage systems that leave a protective mulch of crop residues at the soil surface, or that leave the soil surface rough and porous, are often called conservation tillage systems. Figures 17 and 18 illustrate the effectiveness of these conservation tillage systems in reducing soil erosion from a 5-percent slope in simulated rainfall tests on a Catlin silt loam at Urbana. Nearly 1,000 pounds of soil per acre was lost from a moldboard-plowed area subjected to 1.25 inches of intense rain. Nearly 4 inches of water was required to erode that amount of soil where a chisel plow, disk, or no-tillage system was used. Soil erosion after soybeans was considerably greater than after corn, but conservation tillage resulted in greatly reduced soil loss compared to that from moldboard plowing.

Conservation tillage will not completely control water erosion on all soils; contouring is necessary for all tillage systems on sloping soils. Chisel plows, for example, often leave shallow furrows that can concentrate rainwater and erode severely if the tillage direction is uphill and down. Long or steep slopes may also require terraces or other practices. Contact your district conservationist, Soil Conservation Service for technical assistance in developing erosion control systems.

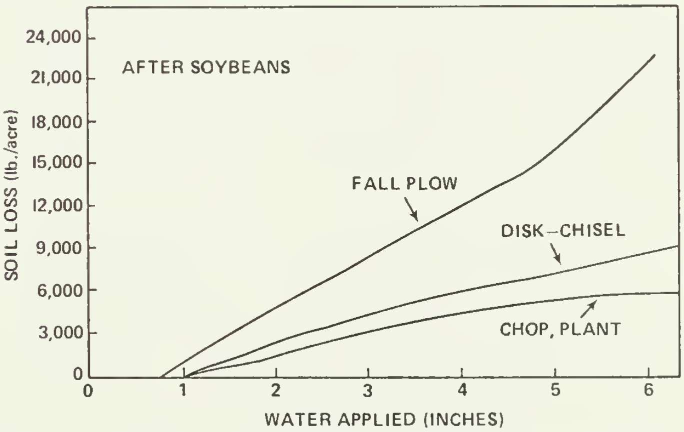
Water and Nutrient Losses

Water runoff starts earliest on soils with the smoothest surfaces, such as those created by moldboard plow, disk, and zero-tillage systems. Since the rough surface of chisel-plowed soil provides barriers to runoff, more water is required before runoff occurs.

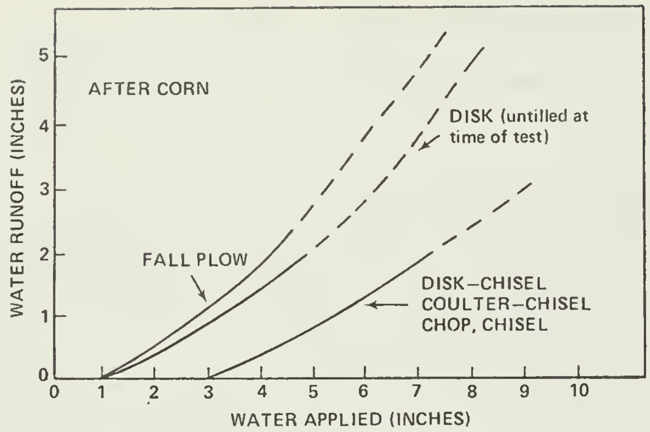
Of the first 4 inches of water applied before spring tillage after corn in the simulated rainfall tests at Urbana, the runoff was 2 inches from fall-plowed soil, 1.5 inches from untilled soil, and less than 0.25 inch from chisel-plowed soil (Figure 19). Differences in runoff after planting were not as great because the soil surface was smoothed by secondary tillage and planting operations.



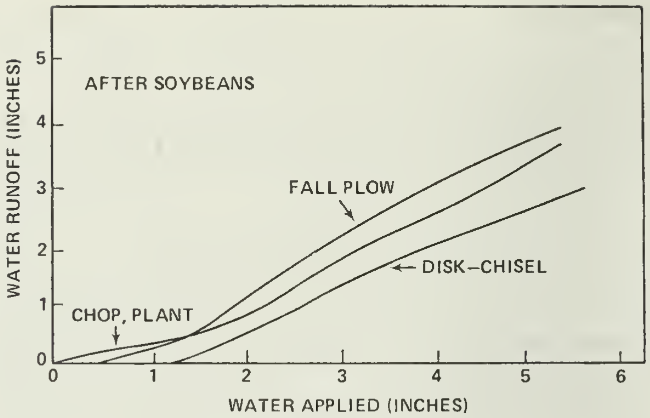
Soil loss following corn and before spring tillage (1974). (Fig. 17)



Soil loss following soybeans and before spring tillage (1974). (Fig. 18)



Water runoff for tillage treatments after corn. (Fig. 19)



Water runoff for tillage treatments after soybeans. (Fig. 20)

Runoff after soybeans was much higher than after corn, and there were only slight differences between treatments (Figure 20). Thus, runoff after soybeans is very difficult to control with common tillage systems.

Only small amounts of nitrogen and phosphorus were lost in runoff water with any of the tillage systems. Measurements of total nitrogen and total phosphorus losses correlated directly with soil losses. Thus, most nutrient losses will be controlled if soil erosion is controlled.

Crop Production with Conservation Tillage

Crop germination, emergence, and growth are largely regulated by soil temperature, moisture content, and nutrient placement. Tillage practices influence each of these components of the soil environment. Conservation tillage systems differ from conventional clean tillage in several respects.

Soil temperature. Crop residue on the soil surface insulates the soil from the sun's energy. Higher soil temperatures than normal are desired for early plant growth. Later in the season, cooler temperatures than normal are desired, but complete crop canopy at that time restricts any influence crop residue might have on soil temperature.

Minimum soil temperatures occur between 6 and 8 a.m. Tillage or crop residue has little effect on minimum soil temperature. Maximum soil temperatures at a depth of 4 inches occur between 3 and 5 p.m. During May, fields tilled by the fall-plow method have soil temperatures 3° to 5° F. warmer than those with a mulch of cornstalks.

The main effect of tillage on soil temperature occurs from late April until the crop forms a canopy that shades the soil surface. During May and early June, the lower soil temperatures caused by a mulch are accompanied by slower growth of corn and soybeans. The growth differences are greatest in years with above-normal rainfall. In dry years, there is little difference in early growth. Whether the lower soil temperature and subsequent slower early growth result in reduced yields depends largely on weather conditions during the summer, particularly during tasseling and silking. Slower growth may delay this process until weather conditions are better, but best yields normally occur when corn tassels and silks early.

Soil moisture. Surface mulch reduces evaporation. Wetter soil is an advantage in dry summer periods, but a disadvantage at planting time and during early growth on soils with poor internal drainage.

Stand establishment. Good contact between the seed and moist soil, uniform planting depth, and enough loose soil to cover the seed are necessary to produce uniform stands. Shallower than normal planting in the cool, moist soil common to many conservation tillage seedbeds may partially offset the disadvantage of lower temperatures, providing that a uniform depth is maintained and seeds are covered. Check planter adjustments frequently.

Planters must be equipped to handle the large amounts of crop residue and firm soil in no-till and some other conservation tillage seedbeds. A coulter, sweep, disk blades, or other narrow tillage equipment can be mounted ahead of the planter unit to handle residue in the row area and open a slot in the soil for seed placement. Extra weight on the planter may be necessary to penetrate firm, undisturbed soil.

Fertilizer placement. Phosphorus and potassium fertilizers and limestone are not mobile in the soil; they remain at or near the soil surface unless they are moved by a tillage operation. This movement is least with a no-till system and greatest when soils are moldboard plowed. Research has shown that surface-applied fertilizers remain in the upper 2 inches of soil with no-till; in the upper 3 to 4 inches with chisel plow or disk tillage; and are uniformly distributed throughout the plowed layer when the tillage system includes moldboard plowing. Roots can use nutrients placed close to the surface with conservation tillage because the crop residue mulch tends to keep soil moist. Experiments in Illinois have not shown that a nonuniform distribution of fertility due to conservation tillage reduces yields and should not be a major concern in deciding to adopt a conservation tillage system.

Nitrogen can be applied to the soil surface or injected as anhydrous ammonia or low pressure solutions. A coulter mounted ahead of the applicator knife may be needed if anhydrous ammonia is applied through heavy trash. Care must be taken to insure a good seal behind the applicator; special packing wheels may be needed for the firm soil of no-tillage systems. Surface-applied solutions containing urea as the nitrogen carrier are subject to nitrogen loss unless incorporated or moved into the soil by rain. Large amounts of surface trash can interfere with soil entry and increase the potential for loss. Surface-applied ammonium nitrate has been from 10 to 20 percent more efficient than urea for no-till corn in Illinois experiments.

Research indicates that from 10 to 20 percent more nitrogen may be required for no-till than for conventional tillage. This need may result from a reduced rate of nitrogen release from organic matter caused by the lower soil temperature, and from an increased potential for denitrification losses caused by the wetter soils.

Weed Control

Weed control is essential for profitable crop production with any tillage system. Cloddy soil surfaces and crop residues left by some tillage systems interfere with herbicide distribution and incorporation. Herbicide rates must not be skimpy, especially with conservation tillage. (Consult the row crop weed control guide, page 73, for specific herbicide recommendations.)

Problem weeds. Perennial weeds such as milkweed and hemp dogbane may be a greater problem with conservation tillage systems. Current programs for control of weeds such as johnsongrass and yellow nutsedge call for high rates of preplant herbicides that should be thoroughly incorporated. Wild cane is another weed that is best controlled by preplant, incorporated herbicides. Volunteer corn is often a problem with tillage systems that leave the corn relatively shallow. Surface germinating weeds, such as fall panicum and crabgrass, may also increase with reduced tillage systems unless control programs are monitored closely.

Herbicide application. Surface-applied and incorporated herbicides will not give optimal performance under tillage systems that leave large amounts of crop residue and clods on the soil surface. These problems interfere with herbicide distribution and thorough herbicide incorporation.

Herbicide incorporation is impossible in no-till systems. Residual herbicides must be effective since mechanical cultivation is usually not done. Residual herbicide rates may need to be higher under no-till and reduced tillage systems because of herbicide tie-up on crop residues. Increasing the volume of spray per acre in heavy vegetation or surface residues may improve the performance of most herbicides. Be sure to follow herbicide label instructions.

Cultivation. The crop can be cultivated with all tillage systems except, possibly, no-till with heavy trash.

High amounts of crop residues may interfere with some rotary hoes and sweep cultivators. Disk cultivators will work, but may tend to bury too much of the residue for effective erosion control. Rolling cultivators are effective across a wide range of soil and crop residue conditions.

Herbicide carryover. Herbicide carryover potential is greater in conservation tillage systems because higher herbicide rates may be needed, and because there is less dilution of herbicides with the soil when moldboard plowing is not done. Herbicide carryover is affected by climatic factors and soil conditions. Warm, wet weather and soils lead to faster breakdown than do cool, dry conditions. Soils with a pH above 7.4 tend to have greater atrazine carryover problems than those with pH values from 6.0 to 7.3.

The carryover problem can be reduced by using less of the more persistent herbicides in combination with other herbicides, or by using less persistent herbicides. Early application of herbicides reduces the potential for herbicide carryover.

Carryover can be detected by growing a sensitive species (bioassay) in soil samples from suspected fields to detect harmful levels of persistent herbicides. Carryover is not a problem if the same crop or a tolerant species is to be grown the next cropping season.

No-till weed control. Existing weed growth is destroyed before planting in conventional and in most conservation tillage systems. No-till systems require a knockdown herbicide like Paraquat or Roundup to control existing vegetation. This vegetation may be a grass or legume sod, or early germinating annual and perennial weeds. Alfalfa, marestail, and certain perennial broadleaf weeds will not be controlled by Paraquat. It may be necessary to treat these with Banvell or 2,4-D either before Paraquat application or after regrowth. Do not apply these translocated herbicides with Paraquat since the contact action to the foliage may prevent translocation.

Insect Control

Insects should not limit the adoption of conservation tillage systems. Most soil insect problems in corn that might be magnified by conservation tillage practices can be controlled with soil insecticides applied at planting. Outbreaks of above ground foliage-feeding pests can be controlled with properly timed sprays. Close monitoring of fields with insect outbreaks is very important.

Insect populations are greatly affected by soil texture, chemical composition, moisture content, temperature, and organisms in soils. Tillage operations affect some of these soil conditions and change the environment in which the insects must survive. Some tillage operations favor specific pests while others tend to reduce pest problems. Since insect species differ in life cycles and habits, each must be considered separately.

Northern and western corn rootworms are the primary soil insect pests of corn in Illinois. Damage is primarily confined to corn following corn. Research shows that there is no indication that reduced tillage systems (no-till, chisel, disk) increase corn rootworm damage. Although a specific tillage practice might affect corn rootworm populations in some fields in some years, tillage, regardless of the type, is not an important factor in regulating corn rootworms. Moldboard plowing is not recommended as a control measure for corn rootworms.

European corn borer larvae overwinter in corn stalk residues. Tillage systems that leave corn stalks on the surface could result in increased populations of first-generation moths and subsequent damage by the first brood in late June or early July.

Black cutworm outbreaks in corn appear more frequently with conservation tillage systems than in conventionally tilled fields, probably because cutworm moths deposit eggs on vegetation or surface debris. Recent research by the Illinois Natural History Survey indicates that egg-laying occurs prior to planting. Chickweed and other winter annual weeds not buried by tillage serve as hosts for egg-laying and cutworm survival. Research indicates that both weediness and reduced tillage practices may contribute to cutworm problems.

No-Till Pest Problems

Insect problems occur more frequently in no-till corn than in other conservation tillage systems, and are often more serious. No-till gives pests a stable environment for survival and development. Soil insecticides can be profitably applied to corn following grass sod or in any rotation where grass and weeds are prevalent. It does not generally pay to apply a soil insecticide to no-till corn following corn (except in rootworm infested areas), soybeans, or a small grain. A diazinon planter-box seed treatment should, however, be used to protect against damage by seed-corn beetles and seed-corn maggots.

Table 55 provides information on the effects of tillage practices on pest problems in corn, based on estimates of extension entomologists.

Disease control. The potential for plant disease is greater when mulch is present than it is when fields are clear of residue. With clean tillage, residue from the previous crop is buried or otherwise removed. Since buried residue is subject to rapid decomposition, infected residue is likely to be removed through decay.

Volunteer corn is likely to be a problem unless the soil is moldboard-plowed in the fall or the zero-till system is used. If the volunteer corn is a disease-susceptible hybrid, the possibility for early infection with diseases such as southern corn leaf blight increases.

Although the potential for plant disease is greater with mulch tillage than with clean tillage, the erosion control benefit of mulch tillage is great. This benefit needs to be balanced against the increased potential for disease. Disease-resistant hybrids and varieties can be used to

Table 55. — Estimate of the Effect of Different Tillage Practices on Insect Populations in Corn[a]

Pest	Spring plowing	Fall plowing	Reduced tillage	No-till[b]	Effective chemical control[c]
Seed-corn beetles . .	0	0	?	+	Yes
Seed-corn maggots.	0	0	?	+	Yes
Wireworm	0	—	?	+ (Sod)	Yes
White grubs	0	—	?	+ (Sod)	Yes
Corn root aphids . .	—	—	?	+ (Sod)	?
Corn rootworm . . .	0	0	0	+ (Corn)	Yes
Black cutworms . . .	?	?	?	+	Yes
Billbugs	—	—	—	+ (Sod)	Yes
European corn borer	—	—	+	+	Yes
True armyworms . .	—	—	—	+ (Sod)	Yes
Common stalk borer	—	—	—	+	Yes
Slugs	—	—	—	+	No

[a] + = the practice will increase the populations or potential for damage by the pest.
— = it will reduce the population or potential for damage.
0 = no effect on the pest.
? = effect unknown on the pest.

[b] The preceding crop will have a direct influence on the pest problem(s) in no-till corn.

[c] More specific information on insect pest management is presented in the current *Insect Pest Management Guide — Field and Forage Crops*. This circular is revised annually; only the latest edition should be used.

reduce problems of plant disease. Crop rotation or modification of the tillage practice may be justified if a disease problem appears likely.

Crop Yields

Conservation tillage systems have produced yields comparable to those from conventional tillage on most Illinois soils when stands are adequate and pests are controlled. Yields on poorly drained fine-textured soils (silty clay loam, silty clay, and clay) have been consistently higher when soils are moldboard-plowed after corn. Soils with root-restricting claypan or fragipan subsoils, on the other hand, have frequently produced higher corn yields where moisture conserving conservation tillage is used (Table 56).

Symerton silt loam is a dark prairie soil with good internal drainage that is free of root restricting layers in the upper 40 to 48 inches. Yields with chisel plow and conventional systems have been nearly identical. No-till corn yields are lower due to inadequate weed control.

Drummer silty clay loam is a dark, heavy, poorly drained prairie soil that is sticky and compacts easily if tilled when wet. A cornstalk mulch with chisel, disk, or zero-tillage results in slow early growth and lower yields. Corn yields with chisel and spring disk systems are similar to yields with conventional tillage following soybeans.

Cisne silt loam is a poorly drained claypan soil that is common in south-central Illinois. The claypan subsoil restricts root development and water use by the crop. Reduced evaporation with the cornstalk mulch of chisel and zero-till systems conserves water for crop use, frequently resulting in higher yields than with clean tillage.

Grantsburg silt loam is a light-colored, sloping soil that is common in southern Illinois. A dense hardpan

or fragipan in the subsoil restricts root development. The residue mulch with conservation tillage frequently produces higher yields as a result of moisture conservation.

Production Costs

Will the switch from a conventional moldboard plow system to a conservation tillage system be profitable? The answer depends on how one weighs the importance of three primary factors: yield, cost, and erosion control. The relation of yield to the tillage system used has been discussed in the preceding section.

One of the major production costs affected by the choice of tillage system is machinery investment. If you do not already have tillage equipment on hand and have to purchase new machinery, the capital investment and the depreciation and interest costs of the equipment needed for conservation tillage will be somewhat less than for conventional tillage because the implements and power units can be smaller. Of course, if conservation tillage is used on only a part of the land farmed, larger equipment would be needed for the other portion, and thus there would be no savings.

With a conservation tillage system, there will be some reduction in labor because there are no fall or spring tillage operations. The labor saved in this way has value only if it reduces hired labor costs or if the saved unpaid labor is directed into other productive activities such as raising livestock, farming more acres, or reducing machinery costs by substituting smaller machines.

One cost increase sometimes associated with a conservation tillage system is the cost of additional or more expensive pesticides and fertilizers (for example, contact herbicides are needed with no-tillage systems). These increases must be weighed against the reduced fuel and machinery repair costs involved in performing fewer operations. The resulting total cost shows no clear advantage for any reasonable tillage system as long as equivalent yields are obtained.

On many farms it may not be feasible or necessary to switch completely from the conventional moldboard plow system to a single conservation tillage system. Table 57 shows the results of using a combination of a moldboard system on flat ground and a no-till system on sloping land. Adopting a no-till system on those acres where erosion control is necessary would increase fixed machinery, pesticide, and fertilizer costs for the entire farm but would also reduce repair, fuel, and labor costs.

The major advantage of reduced tillage is improved erosion control. With an appropriate soil conservation practice such as contouring, soil losses can reach the tolerance level under alternative systems or rotations. Therefore, if the objective is to meet that level, a conservation tillage system such as no-till would cost less on grain farms than an alternate method such as a less intensive rotation of corn, soybeans, oats, and meadow.

Table 56. — Corn Yields with Plow, Chisel, and No-Tillage Systems

Tillage system	Well drained Symerton silt loam[a]	Poorly drained Drummer silty clay loam[b]	Claypan Cisne silt loam[c]	Fragipan Grantsburg silt loam[d]
	Bushels per acre			
Moldboard plow..	112	165	87	112
Chisel plow	110	159	114	
No-till	99	144	108	115

[a] Elwood, 1972-75.
[b] Urbana, 1974-77.
[c] Brownstown, 1974-77.
[d] Dixon Springs, 1967-76.

Table 57. — Estimated Production Costs and Soil Losses with Different Tillage Systems, Crop Rotations, and Conservation Practices

Tilltage systems and rotations	Machinery depreciation and interest	Machinery repair and fuel	Pesticide	Fertilizer	Direct labor	Soil loss[a]: 2 percent slope, no conservation practice	Soil loss[a]: 5 percent slope, no conservation practice	Soil loss[a]: 5 percent slope, contoured
	Dollars per acre	*Dollars per acre*	*Dollars per acre*	*Dollars per acre*	*Hours per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*
CORN-SOYBEAN ROTATION								
Moldboard and chisel	43	26	14	42	1.9	6.4	25.1	12.6
Chisel	43	24	16	42	1.7	4.5	17.1	8.6
Tandem disk	40	19	17	42	1.4	3.8	14.5	7.3
No-till	36	14	28	46	1.0	.9	3.4	1.7
Combination: moldboard on flat ground, no-till on sloping land ...	44	22	21	44	1.6	6.4[b]	3.4[c]	1.7[c]
CORN-SOYBEAN-OATS-MEADOW ROTATION								
Moldboard	38	14	8	20	1.4	2.5	9.6	4.8

[a] Calculated for Flanagan and Catlin soil types using formulas and data from R. D. Walker and R. A. Pope, *Estimating Your Soil Erosion Losses with the Universal Soil Loss Equation (USLE).*
[b] Only moldboard used.
[c] Only no-till used.

MOISTURE MANAGEMENT

An important means of increasing crop yields is to improve moisture management. By eliminating moisture stress, you will be better able to obtain the benefits of improved cultural practices and realize the genetic potential of the cultivars now available.

To produce maximum yields, the soil must be able to provide water as it is needed by the crop. But the soil seldom has just the right amount of water for maximum crop production. Usually, there is either a deficiency or a surplus. A good moisture management program seeks to avoid both extremes through a variety of measures. These include draining waterlogged soils; making more effective use of the water-holding capacity of soils, so that crops will grow during periods of deficient rainfall; increasing the soil's ability to absorb moisture and conduct it down through the soil profile; reducing the loss of moisture from the soil surface; and perhaps diverting, harvesting, and storing water (either in surface impoundments or underground) during periods of excessive rainfall, so that it can be used for irrigation during dry seasons.

Excess water in the soil limits the amount of oxygen available to plants and as a result retards their growth. This problem occurs where there is either a high water table or ponding of water on the soil surface. Removing this excess water from the root zone is an important first step toward a good moisture management program. A drainage system should be capable of removing water from the soil surface and lowering the water table to about 12 inches beneath the soil surface in 24 hours and 21 inches in 48 hours.

The Benefits of Drainage

By installing a well-planned drainage system, you can derive a number of benefits: better soil aeration, more time for performing field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

Soil aeration. Good drainage ensures that roots and microorganisms in the soil receive enough oxygen to develop properly. When the soil becomes waterlogged, aeration is impeded, causing a decrease in the amount of oxygen available. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also increases resistance to the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency. Prolonged oxygen deficiency may result in the death of some cells, entire roots, or in extreme cases the whole plant.

Timeliness. Because a good drainage system increases the number of days available for planting and harvesting, it can enable you to make more timely field operations. It can reduce the likelihood that planting will be delayed and that good crops will be drowned out or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for the additional equipment that is sometimes necessary where fields remain wet for long periods and fewer days are available for field operations.

Soil temperature. Drainage can increase the temperatures at the surface of the soil during the early months of the growing season by 6° to 12° F. Warmer temperatures assist germination and increase plant growth.

Surface runoff. By better enabling the soil to absorb and store rainfall, drainage reduces runoff of water from the soil surface and as a result reduces soil erosion.

Soil structure. Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, causing the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil to cease. The structure of the saturated soil will suffer further damage if you perform tillage or harvesting operations on it.

Herbicide incorporation. Good drainage can help you avoid costly delays in herbicide application, particularly of postemergence herbicides. These herbicides must sometimes be applied while the weeds are still relatively small. Since the weeds remain so for only a short period, you may not be able to make a timely application unless you have an adequate drainage system that keeps the soil dry enough for field operations. Drainage may also help relieve the cool, wet stress conditions that make crop injury by some herbicides more severe.

Root development. Good drainage enables plants to send roots deeper into the soil so they can extract moisture and plant nutrients from a larger volume of soil. Plants that have deep roots are better able to withstand drought.

Crop yield and quality. All these benefits contribute to greater yields of higher quality crops. The exact amount of the increase in yield and quality depends on the type of soil, the amount of rainfall, the fertility of the soil, the crop management practices you use, and the level of drainage before and after improvements are made. Only a few studies have been conducted to determine the benefits of drainage. The most extensive study conducted in Illinois was initiated on the Agronomy Research Center at Brownstown. This study evaluated drainage and irrigation treatments with Cisne and Hoyleton silt loams. Yield information over the last seven years is summarized on pages 69 and 70.

Drainage Methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system you need depends in part upon the ability of the soil to transmit water.

Surface Drainage

A surface drainage system is most appropriate on flat land having slow infiltration and low permeability and on soils with restrictive layers close to the surface. With this type of system, excess water is removed from the soil surface through improved natural channels or man-made ditches and through shaping of the surface of the land. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

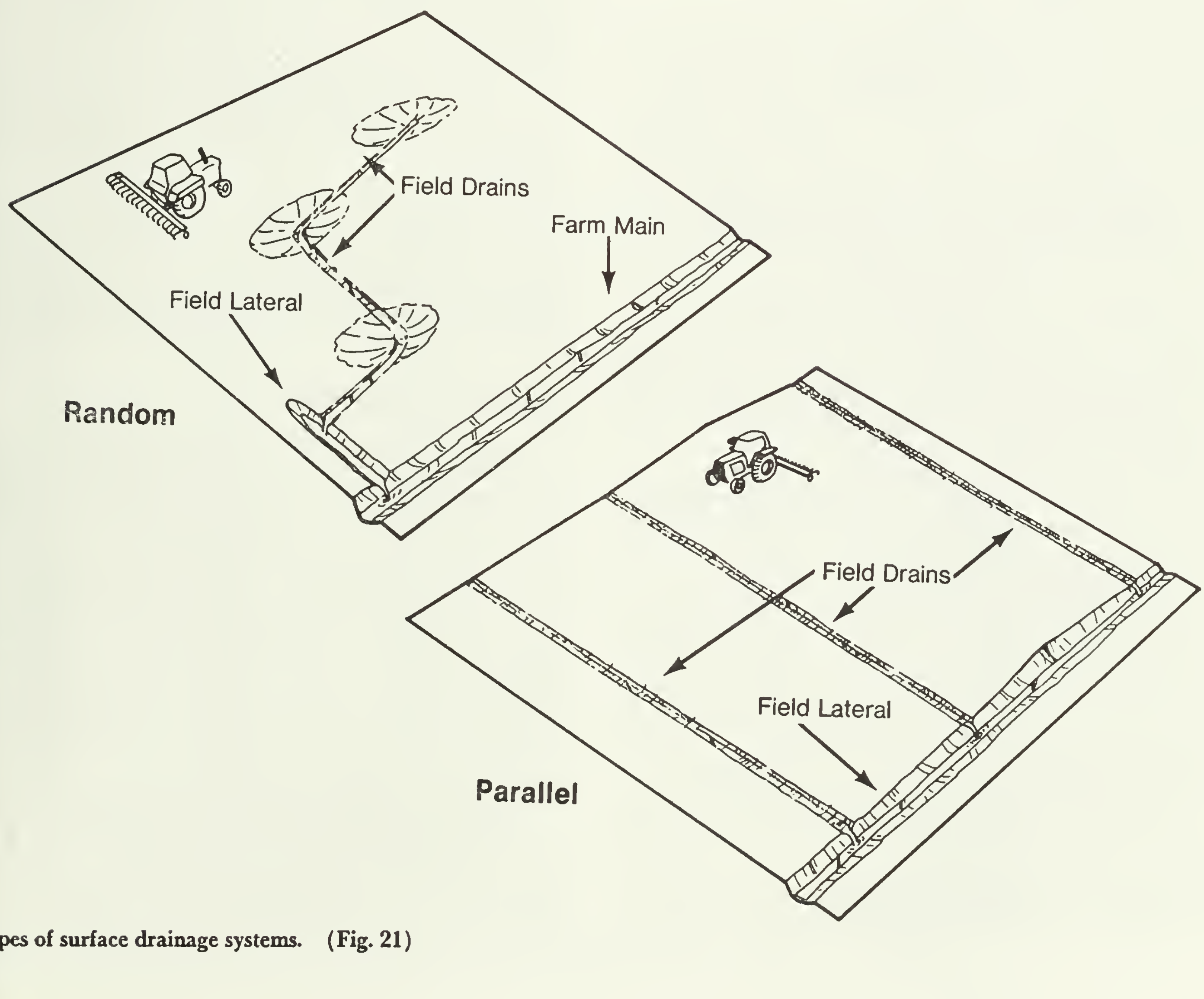
A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, it may be desirable to let a surface drain or waterway covered with vegetation serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains or sometimes from the surface of the field and carry it to the farm main. Field drains are shallow, graded channels with relatively flat side slopes; these drains collect water within a field.

Two other components that are sometimes included in a surface drainage system are diversions and interceptor drains. Diversions are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. These channels are usually located at the base of a hill. Diversions simplify and reduce the cost of drainage for bottomlands.

Interceptor drains are channels installed to collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have 1 percent or steeper grades and on shallow, permeable soils overlying relatively impermeable subsoils. The location and depth of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage systems are the random and parallel systems (Figure 21). The random system is made up of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils having depressions that are too large to be eliminated by smoothing or shaping of the land.

The parallel system is suitable for flat, poorly drained soils that have numerous shallow depressions. In a field that is cultivated up and down its slope, parallel ditches



Types of surface drainage systems. (Fig. 21)

can be placed so as to break the field into shorter lengths. The excess water thus erodes less soil because it flows over only a relatively small part of the field surface before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, you must eliminate minor depressions and irregularities in the soil surface through land grading or smoothing.

Bedding is another surface drainage method that is occasionally used. The land is plowed to form a series of low, narrow ridges separated by parallel, dead furrows. The ridges are oriented in the direction of the steepest slope in the field. Bedding is adapted to the same conditions as the parallel system. However, bedding interferes more with farm operations, and it does not drain the land as completely. Under most conditions, it is not suitable for land planted in row crops because rows adjacent to the dead furrows will not drain satisfactorily. Bedding is acceptable for hay and pasture crops, although it will cause some crop loss in and adjacent to the dead furrows.

Subsurface Drainage

A subsurface drainage system is used in soils that are permeable enough that the drains do not have to be placed too close together. If the spacing is too narrow, the system will not be economical. The soil must also be productive enough to justify the investment. Further, since a subsurface drainage system functions only as well as the outlet, you must make sure that a suitable outlet is available or that one can be made. Consider too the topography of your fields, keeping in mind that the installation equipment has depth limitations and that a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drains are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or plastic.

There are four types of subsurface systems: the random, herringbone, parallel, and double-main systems (Figure 22). You may need either a single system or some combination of systems. Choose the one or ones that best fit the topography of your land.

For rolling land, you should plan to have a **random** system installed. With this system, the main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be in a gridiron or herringbone pattern to provide the required drainage.

With the **herringbone** system, the main or submain is often placed in a narrow depression. The main may also be located on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system is sometimes combined with other systems to drain small or irregular areas. One of its disadvantages is that because two laterals intersect the main at the same point there may be more drainage than is necessary at that point. This system may also cost more since it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils that are found in narrow depressions.

The **parallel system** is similar to the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations of it are often used with other patterns.

The **double-main system** is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet because of seepage from higher ground. A main is placed on each side of the depression to intercept the seepage water and provide an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, it would be necessary to change the grade of each lateral at some point before it reaches the main. With a double-main system, you can avoid this situation and keep the gradelines of the laterals uniform.

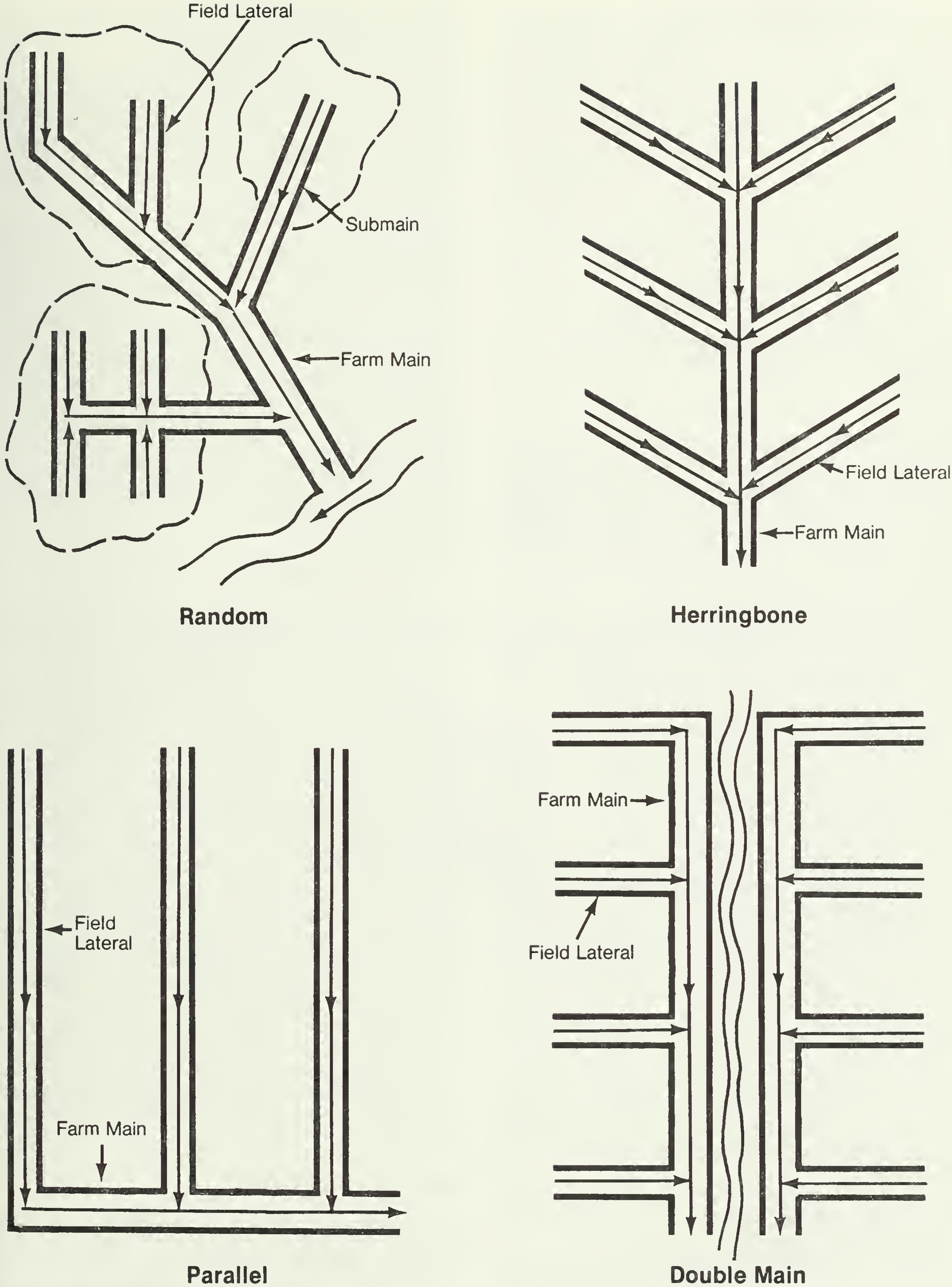
The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than surface drainage. Subsurface drains placed 48 inches deep and 80 to 100 feet apart are suitable for crop production on many medium textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground, they do not obstruct field operations.

For more specific information on surface and subsurface drainage systems, you can obtain the *Drainage Guide for Illinois* from your county Extension adviser. This publication discusses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climatic conditions.

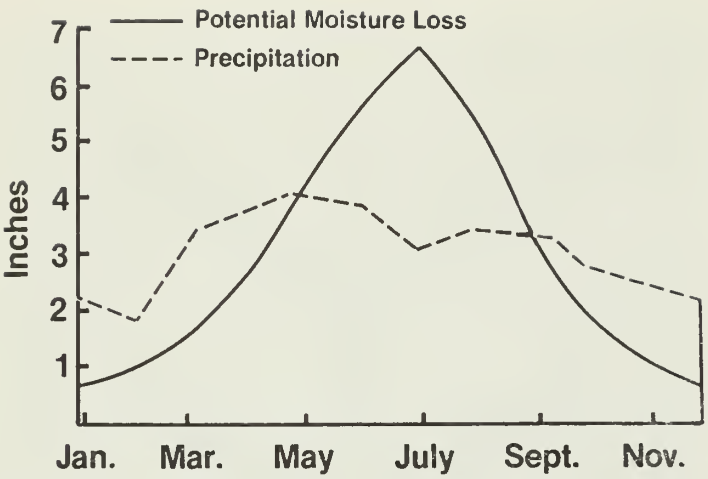
The Benefits of Irrigation

Many regions receive ample rainfall during the year for growing crops, but as shown in Figure 23, the rain or snow does not occur when the crops need it most. During the growing season, crops grown on deep, fine-textured soils may be able to draw upon moisture stored in the soil, assuming that the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding moisture, crop yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils are often unable to provide adequate moisture during the growing season.

To prevent moisture stress during the growing season, more and more producers are using irrigation. Irrigation may be appropriate where moisture stress could substantially reduce crop yields and where a supply of useable water is available at a reasonable cost. Although in



Types of subsurface drainage systems (the arrows indicate the direction of water flow). (Fig. 22)



Average monthly precipitation and potential moisture loss from a growing crop in central Illinois. (Fig. 23)

the United States irrigation is still most widely used in the arid and semiarid states, it can be beneficial in more humid states such as Illinois. Almost every year, drought limits corn and soybean yields to some degree in Illinois, even though the total annual precipitation exceeds the amount of moisture lost through evaporation and transpiration (E.T.).

At least 20 inches of water are needed to produce a good crop of corn or soybeans in Illinois with current cultural practices. All sections of the state average at least 15 inches of rain from May through August. Thus at least 5 inches of stored subsoil moisture are needed in a normal year to produce satisfactory yields.

Crops growing on deep soil with high water-holding capacity (fine-textured soil with high organic matter content) may get by quite well if precipitation is not appreciably below normal and if the soil is filled with moisture at the beginning of the season.

Sandy soils and soils with subsoil layers that restrict water movement and root growth are not able to store as much as five inches of available moisture. Crops on these soils suffer from inadequate moisture every year. Most of the other soils in the state can hold more than five inches of available moisture in the top five feet. Crops on these soils may suffer from moisture deficiency when subsoil moisture is not fully recharged by about May 1 or when summer precipitation is appreciably below normal or poorly distributed through the season.

The probability of getting 1 inch or more of rain in any week is shown in Figure 24. One inch of rain per week will not replace E.T. losses during the summer, but it is sufficient to keep lack of moisture from severely limiting crop growth on soils with reasonably good moisture-holding capacity.

This probability is lowest in all sections of Illinois during the last half of July, when corn normally is pollinating and soybeans are flowering.

Moisture stress delays the emergence of corn silks and shortens the period of pollen shedding, thus reducing the time of overlap between the two processes. The result is incomplete kernel formation, which can have disastrous effects on corn yields.

Data from Iowa State University indicate that corn yields may be reduced as much as 40 percent when four consecutive days of visible wilting are encountered at the time of silk emergence. Their studies have also shown similar yield reductions in soybeans from severe drought during the pod-filling stage.

An increasing number of farmers are installing irrigation systems to prevent the detrimental effects of moisture deficiency. Some years of below-normal summer rainfall and other years of erratic rainfall distribution through the season have been at least partially responsible for the increase. Current high costs of production and some periods of high commodity prices have given added importance to the need for stabilizing yields at high levels. As other yield-limiting factors are eliminated, adequate moisture to assure top yields becomes increasingly important. Most of the irrigation development has been on sandy soils or other soils with correspondingly low levels of available water. Some installations have been made on deeper, fine-textured soils and other farmers are considering irrigation of such soils.

Subsurface Irrigation

Subirrigation has the potential of offering the advantages of good drainage and irrigation in one installation. During wet periods, the system provides drainage to remove excess water. In the irrigation mode, water flows back into the drains and then into the soil by infiltration.

This method is most suitable for land areas of slope less than 2 percent, with either a relatively high water table or an impermeable layer at 3 to 10 feet below the surface. The impermeable layer insures that the applied water will remain where needed, and that a minimum quantity of water will be sufficient to raise the water table.

The free water table should be maintained at 20 to 30 inches below the surface. This level is controlled and maintained at the head control stands, and water is pumped accordingly. In the event of a heavy rainfall, pumps have to be turned off quickly and the drains opened. As a general rule of thumb, the irrigation mode must deliver a minimum of 5 gallons per minute per acre during the growing season.

The soil should be permeable enough to allow rapid water movement, so that plants are well supplied in peak consumption periods. Tile spacing is a major factor in the cost of the total system and perhaps the most important single variable in its design and successful functioning.

Irrigation and Yields

In 1974 irrigation research on corn and soybeans was initiated on Plainfield sand at the Illinois River Valley Sand Field in Mason County. From 1974 to 1976, three frequencies of irrigation were studied: daily, twice a

week, and once a week. Total amount of water per week was constant and was equivalent to about ¼ inch per day. In 1974 corn yields of 180 bushels per acre and soybean yields of 58 bushels per acre were obtained. Nonirrigated yields were not taken in 1974. Corn yields slightly higher than 200 bushels per acre were obtained in 1975 and 1976 with irrigation and with high fertility treatments. Unirrigated corn yielded 70 to 80 bushels per acre with the same fertility treatments. Irrigated corn with no fertilizer added yielded less than 30 bushels per acre on this sandy soil. Full season soybeans yielded 55 and 45 bushels per acre in 1975 and 1976. The yields from non-irrigated soybean plots in those years were 30 and 16 bushels, respectively.

Since 1979 yield comparisons have been made for corn hybrids and soybean varieties under irrigation. Yields as high as 180 bushels for corn and 64 bushels for soybeans have been obtained during the period 1979 through 1983.

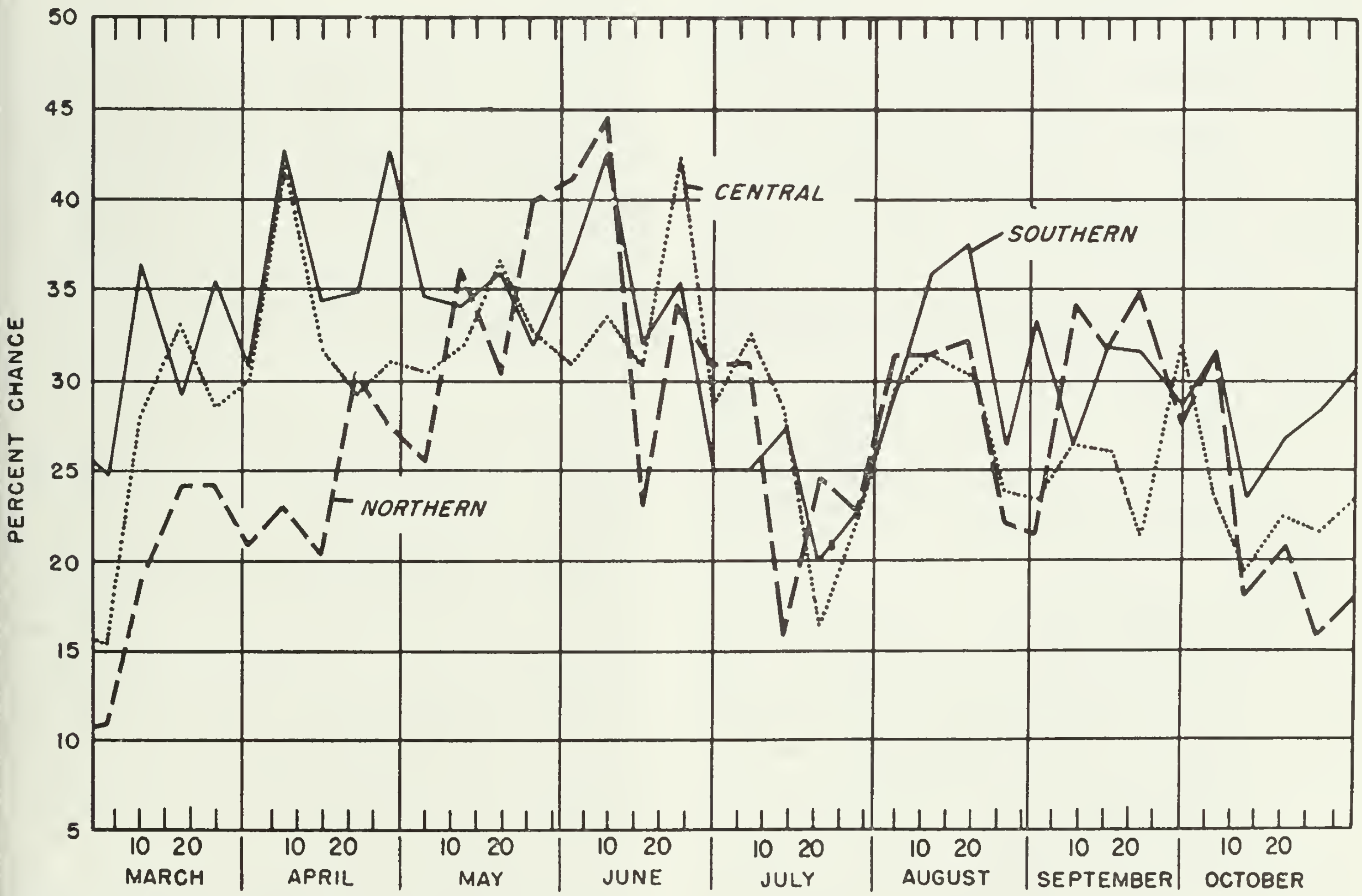
From 1974 through 1978 an experiment on the Sand Field tested the effects of fertilization on irrigated corn plots. Some plots received no fertilizer, some received a 120-60-60 fertilizer, some a 300-150-150 fertilizer, some sludge, and some manure (Table 58). The sludge was applied in amounts sufficient to supply approximately 300 pounds of nitrogen per acre per year. The sludge also supplied adequate phosphorus; however, potash supplements were necessary. The manure supplied about 200 pounds of nitrogen per acre per year. In 1979 the same plots were planted with soybeans without any additional treatment; Table 58 gives yields for both crops. The significantly lower figures for the plots with no fertilizer treatment indicate that adequate fertilization and irrigation are both essential to high yield production.

In 1977 an experiment was initiated on the Agronomy Research Center at Brownstown which evaluates irrigation and drainage variables on Cisne and Hoyleton silt

Table 58. — Corn and Soybean Yields on Fertilized and Unfertilized Irrigated Sand Field Plots

Treatment given 1974–1978	Corn yield 1974–1978	Soybean yield 1979[a]
	Bushels per acre	
No fertilizer	32	58
120-60-60 fertilizer	120	68
300-150-150 fertilizer	184	67
Sludge and potash	179	75
Manure	139	63

[a] No fertilizer given this year.



Chance of one inch or more rain in one week. (Fig. 24)

loams. Surface drainage was accomplished by land shaping to assure uniform, slow runoff. Subsurface drainage was by 3-inch diameter perforated plastic drain tubes installed on 20-foot spacings. The tubes were placed at a shallow depth — just above the clay pan layer. Surface irrigation water was distributed through gated pipe and ran down furrows between the rows. Sprinkler irrigation was by a solid-set system with a low application rate. The water source was a pond constructed on the farm and the plots were in the watershed of the pond. Runoff water, whether from rain or from irrigation, accumulated in the pond.

In 1978 drainage had little effect on corn yields, whereas irrigation increased yields from 53 bushels per acre to 150 bushels per acre. In 1979, however, drainage treatments influenced corn yields more than did irrigation. In this year, water standing for a number of days on the surface of undrained plots reduced yields to only 23 bushels per acre. Plots with subsurface drainage, on the other hand, yielded 160 bushels per acre without irrigation and 195 bushels per acre with irrigation.

Corn plots that had not been drained or irrigated yielded an average of 81 bushels per acre, and those that had received good drainage and irrigation yielded an average of 161 bushels per acre for the seven years 1977 through 1983. The average yield attributable to drainage alone was 18 bushels per acre, and that attributable to irrigation alone was 41 bushels per acre over the seven years. There was little difference in corn yield between plots that had received sprinkler irrigation and those that had received surface irrigation. Subsurface drainage alone gave higher corn yields than surface drainage alone, 99 as compared with 79 bushels per acre, respectively. The combination of surface plus subsurface drainage produced 92 bushels per acre. Of the irrigated plots, those with drainage treatments averaged about 40 bushels per acre more than those without drainage treatments. Of the drained plots, those with irrigation treatments averaged about 70 bushels per acre more than those without irrigation treatments.

Soybean drainage and irrigation treatments were initiated in 1980. To date, soybeans on both irrigated and drained plots showed a yield increase of 10 bushels per acre compared with soybeans grown with neither treatment. Irrigation or drainage alone produced no yield advantage.

In 1979 an irrigation experiment was begun at Norris Mine in Fulton County as part of a comprehensive research program for reclaiming strip-mined land. The water source is a terminal pond formed by the mining operation. Corn grown on unirrigated mine spoil has yielded an average of 92 bushels per acre over the five years 1979-1983. Irrigation increased yields by an average of 48 bushels per acre per year. Corn grown on unirrigated mine spoil with 18 inches of topsoil added averaged 103 bushels per acre over the five years, and irrigation gave an average increase of 78 bushels per acre per year. Soybeans grown on mine spoil with topsoil added averaged 37 bushels per acre without irrigation and only 48 bushels per acre with irrigation during 1980-1983.

Irrigation for Double Cropping

Proper irrigation can eliminate the most serious problem in double cropping: inadequate moisture to get the second crop off to a good start. No part of Illinois has better than a 30-percent chance of getting an inch or more of rain during any week in July and most weeks of August. If one has irrigation equipment, double-crop irrigation should receive high priority in the operational program. If one is not irrigating but is considering it, the possibility of double cropping under irrigation should be taken into account in making the decision. Soybeans planted at Urbana July 6 following wheat harvest have yielded as much as 38 bushels per acre with irrigation.

In Mason County, soybeans planted the first week in July have yielded as much as 30 bushels per acre with irrigation.

While it may be difficult to justify investing in an irrigation system for double-crop soybeans alone, the potential benefits from irrigating double-crop beans added to the benefits from irrigating other crops may make the investment worthwhile. Some farmers report that double cropping will have top priority in their irrigation programs.

Fertigation

The method of irrigation most common in this area — overhead sprinkler — is the one best adapted to applying fertilizer along with water. Fertigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little if any additional cost of application. Nitrogen can be applied during periods when the crop has a heavy demand for both nitrogen and water. Corn uses nitrogen and water most rapidly during the three weeks before tasseling. About 60 percent of the nitrogen needs of corn must be met by silking time. Generally, it is recommended that nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though appreciable uptake occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant's nutrient needs.

In Illinois, fertigation appears to be best adapted to sandy areas where irrigation is likely to be needed even in wettest years. On finer-textured soils with high water-holding capacity, one may be faced with need for nitrogen but with no lack of moisture. Neither irrigating just to supply nitrogen nor allowing the crop to suffer for lack of nitrogen is an attractive alternative. Even on sandy soils, only part of the nitrogen should be applied with irrigation water, with preplant and sidedress applications providing the rest of it.

Other problems associated with fertigation can only be mentioned here. These include (1) possible lack of uniformity of application, (2) loss of ammonium nitro-

gen by volatilization in sprinkling, (3) loss of nitrogen and resultant ground-water contamination by leaching if overirrigation occurs, (4) corrosion of equipment, and (5) incompatibility of some fertilizer materials and low solubility of some. Good discussions of these and factors affecting them can be found in textbooks, scientific journals, farm periodicals, and trade journals.

Cost and Return

In 1984 the annual cost of irrigating field corn with a center-pivot system in Mason County was estimated to vary from $95 to $140 per acre. The lower figure is for a leased low-pressure system with a 50-horsepower electric motor driving the pump. The higher figure is for a purchased high-pressure system with a 130-horsepower diesel engine. Further costs associated with obtaining a yield large enough to offset the cost of irrigation were estimated to be about $30 per acre per year, giving a total cost associated with irrigation of $125 to $170 per acre per year. The total investment for the purchased high-pressure irrigation system, including pivot, pump and gear head, diesel engine, and a 100-foot-deep well, amounted to $490 per acre. If the low-pressure system were purchased, the total investment for the system, including pivot, pump, electric motor, and a 100-foot-deep well, would be $430.

Another important factor in considering irrigation costs is the relationship of these costs to the cost of land. If the capital costs of an irrigation system are $400 per acre and land costs $2,000 per acre, the irrigation equipment cost is 16.7 percent of the total. If the land cost is $4,000 per acre, the same $400 cost for irrigation equipment becomes 9.1 percent of the total. Irrigating existing acreage now under cultivation will help stabilize production from year to year. Many farmers are weighing this alternative against the purchasing or leasing of additional land. One farmer reports that he added irrigation for 160 acres in 1979 at the same cost as that of purchasing an additional 20 acres.

The Decision To Irrigate

If a producer is convinced that it will be profitable for him to install an irrigation system, he must have an adequate source of water. Such sources do not exist at present in many parts of the state. We are fortunate in that underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of Illinois, particularly the northern third, deeper wells may provide a relatively adequate source of water for irrigation.

Many farmers are pumping their water from streams for irrigation. This can be a relatively good and low-cost source; but, of course, the stream may dry up in a drought year. Impounding surface water on an individual farm is possible in many areas of the state, and some farmers are doing that. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. The rule-of-thumb figure is that you probably need to store 2 acre-inches of water for each acre-inch actually applied to the land. Although in many areas the water-development costs may be beyond the range of feasibility for an individual farmer, such development by groups of farmers, cooperatives, or governmental agencies could produce a sufficient water supply in one containment for a number of irrigators.

27,000 gallons of water are required to make a one-inch application on one acre (one acre-inch). A flow of 450 gallons per minute will give one acre-inch per hour. Thus a 130-acre center pivot system with a flow of 900 gallons per minute can apply 1 inch of water over the entire field in 65 hours of operation. Since some of the water is lost to evaporation and some may be lost from deep percolation or runoff, the net amount added will be less than 1 inch.

The Illinois State Water Survey and the Illinois State Geological Survey at Urbana can provide information on the availability of water for irrigation. Submit a legal description of the site on which you plan to develop a well and request information regarding its suitability for irrigation-well development. Once you decide to drill a well, the Water Use Act of 1983 requires you to notify the local Soil and Water Conservation District office if the well is planned with an expected or potential withdrawal rate of 100,000 gallons or more per day. There are no permit requirements or regulatory provisions.

The Riparian Doctrine, which governs the use of surface waters, states that a person is entitled to a reasonable use of the water which flows over or adjacent to his or her land, as long as that person does not interfere with someone else's right to use the water. No problem results as long as there is plenty of water for everybody. But when the amount of water becomes limiting, legal determinations may have to be made as to whether one's use interferes with someone else's rights concerning the water. It may be important to have a legal record established in order to verify the date on which the use of water for irrigation began.

Assuming you believe that it will be profitable for you to irrigate and that you have an assured supply of water, how do you find out what type of equipment is available and what will be best for your situation? University representatives have discussed this question in various meetings around the state; but they cannot, of course, design a system for each individual farm. Your county extension adviser can provide you with a list of dealers located in Illinois and others who serve Illinois. This list gives the kinds of equipment each dealer sells, but will not give you information about the characteristics of those systems.

We suggest that you contact as many dealers as you wish and discuss your needs with them in relation to the type of equipment they sell. You will then be in a much better position to determine what equipment to purchase.

Irrigation Scheduling

Experienced irrigators have developed their own procedures for scheduling applications, whereas beginners may have to determine timing and rates of application before they feel prepared to do so. Irrigators generally follow one of two basic methods of scheduling, each of which has numerous variations. The first method involves measuring soil moisture and plant stress by 1) taking soil samples at various depths with a soil probe, auger, or shovel and then measuring or estimating the amount of moisture available to the plant roots; or 2) inserting instruments such as tensiometers or electrical resistance blocks into the soil to desired depths and then taking readings at intervals; or 3) measuring or observing some plant characteristic and then relating this characteristic to moisture stress. The other method of scheduling, frequently called the "checkbook method," involves keeping a balance of the amount of moisture in the soil by measuring the amount of rainfall and then measuring or estimating the amount of moisture lost from crop use and evaporation. When the moisture level drops to a certain level, the field is irrigated. Computer techniques are also available for estimating moisture loss, computing the moisture balance, and predicting when irrigation is necessary.

Management Requirements

Irrigation will provide maximum benefit only when it is an integral part of a high-level management program. Good seed or plant starts of proper genetic origin planted at the proper time and at a sufficiently high plant population, accompanied by optimum fertilization, good pest control, and other recommended cultural practices, is necessary to assure the highest benefit from irrigation.

Farmers who invest in irrigation may become disappointed if they do not manage the irrigation properly. They often overextend their systems so much that they cannot maintain adequate soil moisture when the crop requires it. For example, the system may be designed to apply 2 inches of water to 100 acres once a week. In 2 or more successive weeks, soil moisture may be limiting, with potential evapotranspiration equaling 2 inches per week. If the system is used on one 100-acre field one week and another field the next week, neither field may receive much benefit, especially if moisture stress comes at a critical time, such as during pollination of corn or seed development of soybeans. Inadequate production of marketable products may result.

Currently we suggest that irrigators follow the cultural practices they would use to obtain the most profitable yield in a year of ideal rainfall. In many parts of the state 1975, 1981, and 1982 were such years. If a farmer's yield is not already appreciably above the county average for that farmer's soil type, he or she needs to improve management of other cultural factors before investing in an irrigation system.

The availability of irrigation on the farm permits the use of optimum production practices every year. If rains should come as needed, the investment in irrigation equipment would not have been needed that year, but no operating costs would have been involved. If rainfall should be inadequate, however, the yield potential could still be realized every year with irrigation.

Illinois Irrigation Newsletter

The University of Illinois College of Agriculture issues the *Illinois Irrigation Newsletter,* which covers items of particular concern to irrigators. A modest subscription charge covers cost of printing and mailing. Subscription forms may be obtained from county Cooperative Extension Service offices or by writing to the Agricultural Newsletter Service, Cooperative Extension Service, 116N Mumford Hall, 1301 W. Gregory Drive, Urbana, Illinois 61801.

1985 ROW CROP WEED CONTROL GUIDE

This guide is based on the results of research conducted by the University of Illinois Agricultural Experiment Station, other experiment stations, and the U.S. Department of Agriculture. Consideration has been given to the soils, crops, and weed problems of Illinois.

The effectiveness of herbicides is influenced by rainfall, soil factors, weed spectrum, method of application, and formulation. Under certain conditions some herbicides may damage the crops to which they are applied. In some cases, herbicide residues in the soil may damage crops that are grown later.

Precautions

When selecting a herbicide, consider both the risk involved in using the herbicide and the yield losses caused by weeds. You can reduce risks by taking the following precautions:

- Apply herbicides only to those crops for which use has been approved.
- Clean tanks thoroughly when changing herbicides, especially when using a postemergence herbicide.
- Correctly calibrate the sprayer and check the nozzle output and adjustment before adding herbicide to a tank.
- Use recommended rates. Applying too much herbicide is costly and in addition may damage crops and cause illegal residues. Using too little herbicide can result in poor weed control.
- Apply herbicides only at times specified on the label. Observe the recommended intervals between treatment and pasturing or harvesting of crops.
- Wear goggles, rubber gloves, and other protective clothing as suggested by the label.
- Guard against drift injury to nearby susceptible plants, such as soybeans, grapes, and tomatoes. Mist or vapors from 2,4-D and dicamba sprays may drift several hundred yards. When possible, operate sprayers at low pressure with tips that deliver large droplets. Spray only on calm days or make sure that wind is not moving toward susceptible crop plants and ornamentals.
- Apply herbicides only when all animals and persons not directly involved in the application have been removed from the area. Avoid unnecessary exposure.
- Check the label for the proper method of container disposal. Triple rinse, puncture, and haul metal containers to an approved sanitary landfill. Haul paper containers to a sanitary landfill or burn them in an approved manner.
- Return unused herbicides to a safe storage place promptly. Store them in the original containers away from unauthorized persons, particularly children.
- Since formulations and labels are sometimes changed and government regulations modified, always refer to the most recent product label.

This guide has been developed to help you use herbicides as effectively and safely as possible. However, since no guide can remove all the risk involved, the University of Illinois and its employees assume no responsibility for the results of using herbicides, even if they have been used according to the suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Cultural and Mechanical Control

Most weed control programs combine good cultural practices, mechanical weed control, and herbicide applications. Good cultural practices that aid in weed control include adequate seedbed preparation, adequate fertilization, crop rotation, planting on the proper date, use of the optimum row width, and seeding at the rate required for optimum stands.

Planting in relatively warm soils helps crops compete better with weeds. Good weed control during the first 3 to 5 weeks is extremely important for both corn and soybeans. If weed control is adequate during that period, corn and soybeans will usually compete quite well with most of the weeds that begin growing later.

Narrow rows will shade the centers faster and help the crop compete better with the weeds. However, if herbicides alone cannot give adequate weed control, then keep

rows wide enough to allow for cultivation. Some of the newer herbicides are improving the chances of achieving adequate control without cultivation.

If a preemergence or preplant herbicide does not appear to be controlling weeds adequately, use the rotary hoe while weeds are still small enough to be controlled.

Use the rotary hoe after weed seeds have germinated but before most weeds have emerged. Operate it at 8 to 12 miles per hour and weight it enough to stir the soil and kill the tiny weeds. Rotary hoeing also aids crop emergence if the soil is crusted.

Row cultivators also should be used while weeds are small. Throwing soil into the row can help smother small weeds. Cultivate shallow to prevent injury to crop roots.

Herbicides can provide a convenient and economical means of early weed control and allow for delayed and faster cultivation. Furthermore, unless the soil is crusted, it is usually not necessary to cultivate at all when herbicides are controlling weeds adequately.

Herbicide Incorporation

Soil-applied herbicides are incorporated to minimize surface loss, reduce dependence upon rainfall, and provide appropriate placement of the herbicide. Sutan+ and Eradicane are incorporated soon after application to minimize surface loss from volatilization. Dinitroaniline herbicides such as Treflan are incorporated within a few hours to minimize loss due to photodecomposition and volatilization. Triazine herbicides such as atrazine and Bladex and acetamide herbicides such as Lasso and Dual may be incorporated to minimize dependence upon timely rainfall, but since these herbicides are not lost as quickly from the soil surface, the time of incorporation is less critical.

Incorporation should place the herbicide uniformly in the top 1 or 2 inches of soil for best control of small-seeded annual weeds that germinate from shallow depths. Slightly deeper placement may improve the control of certain weeds from deep-germinating seed under relatively dry conditions. The field cultivator and tandem disk place most of the herbicide at about one-half the depth of operation. Thus for most herbicides the suggested depth of operation is 3 to 4 inches.

Thorough incorporation with ground-drive implements may require two passes. Single-pass incorporation may result in streaked weed control, especially in wet soils. Single-pass incorporation may be adequate with some equipment, especially if rotary hoeing, cultivation, or subsequent herbicide treatments are used to improve weed control. If the herbicide is sufficiently covered to prevent surface loss with the first pass, the second pass can be delayed until immediately before planting.

The depth and thoroughness of incorporation depend upon the type of equipment used, the depth and speed of the operation, soil texture, and soil moisture. Field cultivators and tandem disks are commonly used for incorporation. However, disk-chisels and other combination tools are being used in some areas.

Field Cultivators

Field cultivators are frequently used for herbicide incorporation. They should have three or more rows of shanks with an effective shank spacing of no more than 8 to 9 inches (a spacing of 24 to 27 inches on each of three rows). The shanks can be equipped with points or sweeps. Sweeps usually give better incorporation, especially when soil conditions are a little too wet or dry for optimal soil flow and mixing. Sweeps for "C" shank cultivators should be at least as wide as the effective shank spacing.

The recommended operating depth for the field cultivator is 3 to 4 inches. It is usually necessary to operate it only deep enough to remove tractor tire depressions. The ground speed should be at least 6 miles per hour. The field cultivator must be operated in a level position so that the back shanks are not operating in untreated soil, which would result in streaked weed control. Two passes are recommended to obtain uniform weed control. If single-pass incorporation is preferred, the use of wider sweeps or narrower spacing with a 3- to 5-bar harrow or rolling baskets pulled behind will increase the probability of obtaining adequate weed control.

Tandem Disks

Tandem disk harrows invert the soil and usually place the herbicide deeper in the soil than most other incorporation tools. Tandem disks used for herbicide incorporation should have disk blade diameters of 20 inches or less and blade spacings of 7 to 9 inches. Larger disks are considered primary tillage tools and should not be used for incorporating herbicides. Spherical disk blades give better herbicide mixing than conical disk blades.

Tandem disks usually place most of the herbicide in the top 50 to 60 percent of the operating depth. For most herbicides, the suggested operating depth is from 3 to 4 inches. Two passes are recommended to obtain uniform mixing with a double disk. A leveling device (harrow or rolling baskets) should be used behind the disk to obtain proper mixing. Recommended ground speeds are usually between 4 and 6 miles per hour. The speed should be sufficient to move the soil the full width of the blade spacing. Lower speeds can result in herbicide streaking.

Combination Tools

Several new tillage tools combine disk gangs, field cultivator shanks, and leveling devices. Many of these combination tools can handle large amounts of surface residue without clogging and yet leave considerable crop residue on the soil surface for erosion control. Results indicate that these combination tools may provide more uniform one-pass incorporation than does a disk or field cultivator, but one pass with them is generally no better than two passes with the disk or field cultivator.

Chemical Weed Control

Plan your weed-control program to fit your soils, tillage program, crops, weed problems, and farming oper-

ations. Herbicide performance depends on the weather and on wise selection and application. Your decisions on herbicide use should be based on the nature and seriousness of your weed problems. The herbicide selectivity table at the end of this guide indicates the susceptibility of our most common weed species to herbicides.

Corn or soybeans may occasionally be injured by some of the herbicides registered for use on those crops. To reduce crop injury, apply the herbicide at the time specified on the label and at the correct rate (see section entitled "Herbicide Rates"). Crop tolerance ratings for various herbicides are also given in the table at the end of this guide. Unfavorable conditions such as cool, wet weather, delayed crop emergence, deep planting, seedling diseases, poor soil physical conditions, and poor-quality seed may contribute to crop stress and herbicide injury. Hybrids and varieties also vary in their tolerance to herbicides and environmental stress factors. Once injured by a herbicide, plants are prone to disease.

Crop planting intentions for the next season must also be considered. Where atrazine or simazine are used, you should not plant spring-seeded small grains, small-seeded legumes and grasses, or vegetables the following year. Be sure that the application of Treflan or similar herbicides for soybeans is uniform and sufficiently early to reduce the risk of injury to wheat or corn following soybeans. Refer to the herbicide label for information on cropping sequence.

Names of Some Herbicides

Trade	Common (generic)
AAtrex, Atrazine	atrazine
Alanap	naptalam
Amiben	chloramben
Banvel	dicamba
Basagran	bentazon
Bicep	metolachlor + atrazine
Bladex	cyanazine
Blazer	acifluorfen
Bronco	alachlor + glyphosate
Buctril, Brominal	bromoxynil
Butoxone, Butyrac	2,4-DB
Dowpon M	dalapon
Dual	metolachlor
Dyanap	naptalam plus dinoseb
Eradicane	EPTC plus safener
Eradicane Extra	EPTC plus safener and extender
Evik	ametryn
Extrazine	cyanazine plus atrazine
Furloe Chloro IPC	chlorpropham
Fusilade	fluazifop-butyl
Hoelon	diclofop-methyl
Laddok	bentazon + atrazine
Lasso	alachlor
Lorox, Linex	linuron
Milogard	propazine
Modown	bifenox
Paraquat Plus, Gramoxone	paraquat
Poast	sethoxydim
Princep, Simazine, Caliber 90	simazine
Prowl	pendimethalin
Ramrod	propachlor
Rescue	naptalam plus 2,4-DB
Reward	vernolate plus extender
Roundup	glyphosate
Sencor, Lexone	metribuzin
(several)	2,4-D
Sonalan	ethalfluralin
Surflan	oryzalin
Sutan+, Genate Plus	butylate plus safener
Sutazine	butylate plus safener plus atrazine
Treflan	trifluralin
Vernam	vernolate

Some herbicides have different formulations and concentrations under the same trade name. *No endorsement of any trade name is implied, nor is discrimination against similar products intended.*

Herbicide Combinations

Herbicides are often combined to control more weed species, reduce carryover, or reduce crop injury. Some combinations are sold as a "package mix," while others are tank mixed. Tank mixing allows you to adjust the ratio to fit local weed and soil conditions. If you use a tank mix, you must follow restrictions on all products used in the combination.

Problems sometimes occur when mixing emulsifiable concentrate (EC) formulations with wettable powder (WP), water dispersible liquid (WDL), or water dispersible granule (WDG) formulations. These problems can sometimes be prevented by using proper mixing procedures. Fill tanks at least one-third full with water or liquid fertilizer before adding herbicides that are suspended. If using liquid fertilizers, check compatibility in a small lot before mixing a tankful. The addition of compatibility agents may be necessary. Wettable powders, WDGs, or WDLs should be added to the tank before ECs. Emulsify ECs by mixing with equal volumes of water before adding them to the tank. Empty and clean spray tanks often enough to prevent accumulation of material on the sides and the bottom of the tank.

The user can apply two treatments of the same herbicide (split application), or he can use two different ones, provided such uses are registered. The use of one herbicide after another is referred to as a sequential or overlay treatment. Sequential treatment can be done in a number of ways. For example, a preplant application might be followed by a preemergence application, or a soil-applied treatment might be followed by a postemergence treatment. One herbicide may be broadcast while the other is banded or directed.

Herbicide Rates

Herbicide rates vary according to the time of application, soil conditions, the tillage system used, and the seriousness of the weed infestation. Sometimes lower rates are specified for preemergence application than for preplant incorporated application. Postemergence rates may be lower than preemergence rates if the herbicides can be applied at either time. Postemergence rates often vary depending on the size and species of the weeds and on whether an adjuvant is specified. Rates for combinations are usually lower than rates for herbicides used alone.

The rates for soil-applied herbicides usually vary with the texture of the soil and the amount of organic matter it contains. For instance, light-colored, medium-textured soils with little organic matter require relatively lower rates of most herbicides than do dark-colored, fine-textured soils with medium to high organic matter. For sandy soils the herbicide label may specify "do not use," "use a reduced rate," or "use a postemergence rather than soil-applied herbicide," depending on the herbicide and its adaptation and on crop tolerance.

The rates given in this publication are, unless otherwise specified, broadcast rates for the amount of formulated product. If you plan to band or direct herbicides, adjust the amount per crop acre according to the percentage of the area actually treated. Many herbicides have several formulations with different concentrations of active ingredient. Be sure to read the label and make the necessary adjustments when changing formulations.

Postemergence Herbicide Principles

Postemergence herbicides applied to growing weeds generally have foliar rather than soil action; however, some may have both. The rates and timing of applications are based on weed size and climatic conditions. Weeds can usually be controlled with a lower application rate when they are small and tender. Larger weeds often require a higher herbicide rate or the addition of a spray additive, especially if the weeds have developed under drouth conditions. Herbicide penetration and action are usually greater when the temperature and relative humidity are high. Rainfall occurring too soon after application (1 to 8 hours, depending on the herbicide) can cause poor weed control.

Translocated (hormone) herbicides can be effective with partial foliar coverage, whereas contact herbicides require more complete coverage. Foliar coverage increases as water volume and spray pressure are increased. Spray nozzles that produce small droplets also improve coverage. For contact herbicides, 20 to 40 gallons of water per acre are often recommended for ground application and a minimum of 5 gallons per acre for aerial application. Spray pressures of 30 to 50 psi are often suggested with flat-fan or hollow-cone nozzles to produce small droplets and improve canopy penetration. These small droplets are quite subject to drift.

The use of a surfactant or crop oil concentrate may be recommended to improve spray coverage. These spray additives will usually improve weed control but may increase crop injury. Spray additives may be needed only under drouth conditions or on larger weeds.

Crop size limitations may be specified on the label to minimize crop injury and maximize weed control. If weeds are smaller than the crop, basal-directed sprays may minimize crop injury because they place more herbicide on the weeds than on the crop. If the weeds are taller than the crop, rope-wick applicators or recirculating sprayers can be used to place the herbicides on the top of the weeds and minimize contact with the crop. *Follow the label directions and precautions for each herbicide.*

Conservation Tillage and Weed Control

Conservation tillage refers to tillage methods that provide efficient crop production along with adequate control of soil erosion caused by wind and water. Erosion is controlled by protecting the soil surface with plant residue. The amount of tillage is less than that used in conventional moldboard plowing. Chisel plowing, ridge tilling, or no tillage can be used; several other systems are also available.

With reduced tillage systems, there is often a greater reliance on herbicides for weed control. With these systems, herbicides cannot be incorporated without covering much of the residue that is necessary for effective erosion control. The early application of preplant, preemergence, and postemergence herbicides is an alternative to incorporation.

Early preplant herbicides may be applied several weeks before planting. Early application may reduce the need for a contact herbicide at planting. However, early preplant application may require additional herbicides (preemergence or postemergence) or cultivation for satisfactory weed control.

Table 1. — Registered No-Till Herbicide Combinations

	Alone	Combination			
		Dual	Lasso	Surflan	Prowl
Soybeans					
Lorox	PBR	PR	PBR	PR	P
Lexone	PBR	PR	PBR	PR	P
Sencor	PBR	PR	PBR	PR	P
Corn					
Atrazine	PBR	PR	PBR	—	—
Bladex	PBR	P	PBR	—	—
Princep	BR	PR	PBR	—	—
Atrazine + Bladex	B	P	PB	—	—
Atrazine + Princep	PBR	PR	PBR	—	—
Bicep	PR	—	—	—	—

Knockdown herbicides:
P = Paraquat, Gramoxone (paraquat).
R = Roundup (glyphosate).
B = Bronco = Roundup + Lasso.
— = Not registered.

Compared with preplant incorporated herbicides, preemergence herbicides require less tillage, but their performance is more dependent upon timely rainfall. However, they have performed better than herbicides that are poorly incorporated. With conservation tillage, a higher application rate of surface-applied herbicides may be required for satisfactory weed control, especially in fields with considerable weed infestation or crop residue. Do not, however, use a higher rate than that stated on the label. Use great care when selecting herbicides and choosing application rates.

The use of effective postemergence herbicides, which depend upon foliar rather than soil action, may be a logical choice with some conservation tillage systems.

No-Till and Double-Crop

Corn and soybeans are sometimes planted without seedbed preparation, either in last year's crop residue (no-till) or as a second crop after a small grain harvest or forage removal (double-crop). Because it conserves soil, soil moisture, and time, no-till planting has greatly improved the probability of success with double-cropping.

No-till herbicides must control both existing vegetation and new weed seedlings.

Existing vegetation may be a perennial grass sod, a legume or legume-grass sod, an annual cover crop, or weeds. If a cutting of forages such as alfalfa or clover is removed before no-till planting, control of sod may be poor if herbicides are applied before there is sufficient regrowth. Labeled applications of 2,4-D, Banvel, or possibly Roundup can improve control of broadleaf perennials when used for registered crops, such as corn, soybeans, or sorghum.

Several precautions should be observed in no-till cropping systems. Crop seed should be planted to the proper depth and adequately covered to avoid possible contact with herbicide sprays. (Several herbicide labels give the planting depths that are necessary to avoid possible injury.) Preemergence applications may give better weed control than preplant applications because the planting process may expose untreated soil that contains viable weed seed. The total reliance on chemical weed control and the large amounts of crop residue present under no-till cropping systems may require that the higher labeled herbicide rates be used to obtain acceptable weed control. Early preplant application of herbicides may reduce the need for a foliar knockdown herbicide. A greater reliance on postemergence herbicides may be needed.

Paraquat Plus or Gramoxone (1 or 2 pints per acre) plus a *nonionic* surfactant at ½ pint per 100 gallons of diluted spray is generally used to "knock down" existing foliage before crop emergence. Smartweed, giant ragweed, and fall panicum may not be controlled if they are over 4 to 6 inches high. A minimum of 40 gallons or more of spray per acre is suggested to ensure adequate coverage of the foliage. *Paraquat and Gramoxone are restricted-use pesticides.*

Roundup (3 to 8 pints per acre) is another alternative for control of existing vegetation prior to crop emergence in situations where fall panicum, smartweed, or certain perennial weeds are a problem. Roundup can translocate to the roots to give better control of perennials. Use 10 to 40 gallons of spray volume per acre. Bronco is a formulated mixture of glyphosate (Roundup) plus alachlor (Lasso). Application rates are 4 to 5 quarts per acre. Bronco may be applied in 10 to 30 gallons of water or in 10 to 50 gallons of 28 percent or 32 percent liquid nitrogen solutions. Application with a nitrogen solution should only be made for control of annual weeds that are less than 6 inches tall.

Roundup, paraquat, and Bronco are registered for use in combination with the preemergence herbicides indicated in Table 1. See the sections entitled "Herbicides for Corn" and "Herbicides for Soybeans" for more information on these products.

Herbicides for Corn

All herbicides mentioned in this section are registered for use on field corn and also on silage corn unless otherwise specified. See Table 2 for registered combinations. Herbicide suggestions for sweet corn and popcorn may be found in Circular 907, *1985 Weed Management Guide for Commercial Vegetable Growers.* Growers producing hybrid seed corn should check with the contracting company or inbred-seed producer about tolerance of the parent lines.

Early Preplant (EPP)

Interest in early preplant application is increasing, especially with the trend toward reduced tillage. With the postemergence as well as residual activity of herbicides such as atrazine and Bladex, early weeds such as smartweed can be controlled while they are small, and emergence of others can be curtailed.

The earlier applications are made before planting, the shorter the length of control after planting. To strengthen and lengthen control, an additional application of the same or another herbicide can be considered.

With AAtrex, Dual, or Bicep, preplant surface application may be made using a ⅔ rate up to 45 days before planting, followed by a ⅓ rate at planting. A single application can be made within 30 days before planting.

Bladex may be applied early preplant at labeled rates, but if applied earlier than 15 days before planting, a split application or use of another herbicide at or after planting is suggested. Banvel is approved for preplant use for corn, and 2,4-D is approved in some combinations for corn.

Preplant Incorporation

Some herbicides may be applied prior to planting and incorporated. The time of application will depend on the label directions and field conditions. Herbicides with sufficient residual activity, such as AAtrex, Bicep, and

Dual, may be applied early preplant up to 45 days before planting. However, if applied too early, weed control may not last as long as desired after planting. Incorporation should distribute the herbicide uniformly in about the top 2 inches of soil. Do not apply herbicides too early or incorporate them too deeply.

Sutan+, Genate Plus (butylate), Eradicane, and Eradicane Extra (EPTC) contain crop safening agents. Crop injury is unlikely, but may occur when growing conditions are unfavorable or when certain hybrids are used. Eradicane Extra also contains an extender to lengthen weed control. These herbicides control annual grass weed and can control or suppress shattercane and johnsongrass at higher rates. The rate for Sutan+ and Genate Plus is 4¾ to 7⅓ pints per acre. The rate for Eradicane 6.7E is 3¾ to 7⅓ pints per acre. The rate for Eradicane Extra 6E is 2⅔ to 4 quarts per acre. Use the higher rates for heavy infestations of shattercane and yellow nutsedge and for johnsongrass.

These herbicides should be incorporated into the soil soon after application. Although some labels allow application up to 4 weeks prior to planting, application close to planting time is generally preferable.

Some of these and other herbicides can also be mixed with dry bulk fertilizer. Sutan+ and Eradicane Extra can be injected into the soil with anhydrous ammonia. Injection should be 4 to 5 inches deep with shanks spaced no wider than 8 to 10 inches. This type of application is affected by soil moisture and physical conditions of the soil. Refer to labels for more information on fertilizer-herbicide combinations.

Table 2. — Registered Herbicide Combinations for Preplant Incorporated (PPI) or Preemergence (Pre) Use in Corn

	Atrazine	Bladex	Princep	Atrazine + Bladex	Atrazine + Princep
PPI only					
Eradicane, Eradicane Extra	1	1	1	1	—
Genate Plus	1	1	—	1	—
Sutan+	1	1	1	1	—
PPI or Pre					
Used alone	1,2,3	1,2,3	1,2	1,2,3	1,2
Dual	1,2,3	1,2	1,2	1,2	1,2
Lasso	1,2,3	1,2	2	1,2	—

1 = Preplant incorporated; 2 = preemergence; 3 = early postemergence.
— = Not registered.

Sutan+, Genate Plus, or Eradicane can be tank-mixed with atrazine or Bladex to improve broadleaf control. Sutan+ or Eradicane can be tank-mixed with Princep. The atrazine rate is 2 to 3 pints of 4L or equivalent amounts of 80W or 90WDG per acre. The Bladex rate is 3 to 4 pints of 4L or 2 to 2½ pounds of 80W per acre. Combinations with both atrazine and Bladex are also registered.

Sutazine+ 6L is a 4:1 mixture of Sutan+ and atrazine. The application rate is 5¼ to 10½ pints per acre. Sutan+ plus atrazine, as well as Sutan+, are available as granular formulations.

Preplant or Preemergence Herbicides

Incorporation of the following herbicides is optional, depending upon the weeds to be controlled and the likelihood of rainfall. Incorporation of these herbicides should be shallow but thorough.

AAtrex, Atrazine (atrazine), or Princep (simazine) can be applied anytime during the 2 weeks prior to planting or soon after planting. If rainfall is limited, incorporation may aid performance. Corn tolerance of atrazine and simazine is good, but carryover to subsequent crops can occur.

Princep controls fall panicum and crabgrass better than atrazine but is less effective in controlling cocklebur, velvetleaf, and yellow nutsedge. Princep is less soluble and more persistent than atrazine. Thus, Princep is usually applied preplant. Princep plus atrazine can be used in 1:1 or 2:1 combinations; the total rate is the same as for atrazine used alone.

The rate for atrazine used alone is 2½ to 3¾ pounds of atrazine 80W, 4 to 6 pints of 4L, or 2.2 to 3.3 pounds of AAtrex 90WDG. Atrazine controls annual broadleaf weeds better than it does grasses, and it is often used at reduced rates in tank mix combinations to improve broadleaf weed control. The rate for atrazine in combinations is 1½ to 2 pounds of atrazine 80W, 2 to 3 pints of atrazine 4L, or 1.1 to 1.8 pounds of AAtrex 90WDG. These rates may not provide adequate control of cocklebur, morningglory, and velvetleaf but can reduce the risk of carryover.

You can minimize carryover injury by mixing and applying the herbicides accurately, by applying them early, by using the lowest rates consistent with good weed control, and by tilling the soil to dilute the herbicide. The risk of carryover is greater after a cool, dry season and on soils with a pH over 7.3.

If you use atrazine at more than 3 pounds of active ingredient per acre or if you apply after June 10, plant only corn or sorghum the next year. If you use atrazine in the spring and must replant, then plant only corn or sorghum that year. Do not plant small grains, small seeded legumes, or vegetables in the fall or the following spring. Soybeans planted the year after an application of atrazine can also be affected from carryover, especially if you use Sencor or Lexone.

Bladex (cyanazine) does not persist in the soil as long as atrazine, but atrazine does have the advantage of better corn tolerance. Bladex provides better control than atrazine of fall panicum, giant foxtail, and some other grass weeds, but not all broadleaf weeds. Bladex can be combined with atrazine at 3:1, 2:1, or 1:1 ratios of Bladex to atrazine (see label for rates). The higher ratios will provide better grass control, while the 1:1 ratio will provide better broadleaf weed control.

Rates of Bladex must be selected accurately on the basis of soil texture and organic matter to reduce the possibility of corn injury. Bladex rates are 1½ to 6 pounds of 80W or 1¼ to 4¾ quarts of 4L. You can lessen the risk of corn injury by using reduced rates of Bladex in combinations.

Extrazine 4L is a 2:1 combination of cyanazine and atrazine. It may be applied preplant to the surface, incorporated, or used preemergence. It is approved for use in combination with Lasso 4EC, Dual 8E, Sutan+ 6.7E, or Eradicane 6.7E.

Bladex can be tank-mixed with Lasso, Dual, Ramrod, or Prowl to improve grass control. The Lasso or Dual combination can be applied immediately before planting or after planting. Do not incorporate the Prowl or Ramrod combinations.

Three-way combinations of Bladex plus atrazine plus Lasso, Dual, Sutan+, or Eradicane are registered. The addition of a limited amount of atrazine should improve broadleaf control without increasing concern about carryover.

Lasso (alachlor) or Dual (metolachlor) can be preplant incorporated or applied at the preemergence stage. Preplant incorporation can improve control of yellow nutsedge and can lessen dependence upon rainfall. Incorporation should distribute the herbicide evenly in the top 2 inches of soil.

Lasso and Dual control annual grasses and help control yellow nutsedge. You can improve broadleaf weed control by using atrazine or Bladex or both in preplant combinations or by using atrazine, Bladex, or both in preemergence combinations.

Lasso can be applied anytime during the week before planting corn and shallowly incorporated, or it can be used after planting but before the crop and weeds emerge and within 5 days after the last tillage operation. The rate is 2 to 4 quarts of Lasso 4E or 16 to 26 pounds of Lasso 15G. Use the higher rate for the soil if you plan to incorporate Lasso.

Dual can be applied anytime during the 2 weeks prior to planting corn and shallowly incorporated, or it can be used soon after planting. The rates are 1½ to 4 pints of Dual 8E or 6 to 16 pounds of Dual 25G per acre.

Lasso or Dual plus atrazine can be preplant incorporated or applied after planting until corn is 5 inches tall and grass weeds have not passed the two-leaf stage. Do not apply with liquid fertilizer after the crop emerges. The suggested rate is 1½ to 4 quarts of Lasso or 1¼ to 2½ pints of Dual 8E plus 1½ to 2½ pounds of atrazine 80W, 1 to 2 quarts of atrazine 4L, or 1.1 to 2.2 pounds of AAtrex 90WDG. Dual is also cleared in a combination with atrazine plus Princep.

Dual and Lasso are both formulated as packaged mixes with atrazine. **Bicep** contains 2½ pounds of metolachlor (Dual) and 2 pounds of atrazine per gallon. The rate is 2 to 4 quarts per acre. **Lasso/atrazine** (flowable) contains 2½ pounds of alachlor (Lasso) and 1½ pounds of atrazine per gallon. The rate is 3½ to 4½ quarts per acre.

Dual or Lasso plus Bladex can be applied prior to planting and incorporated, or they can be applied during the preemergence stage after planting. The rate is 2 to 4 quarts of Lasso 4E or 1¼ to 2½ pints of Dual 8E plus 1 to 3¾ pounds of Bladex 80W or 1 to 3 quarts of Bladex 4L. Adjust the rate carefully according to soil texture and organic matter.

Preemergence Herbicides

Ramrod (propachlor) can be applied alone or with atrazine after the corn is planted but before grasses reach the two-leaf stage. Granular formulations should be applied before crop or weeds emerge. Ramrod performs well on soils with over 3 percent organic matter.

Ramrod is irritating to the skin and eyes, so observe label precautions. Corn tolerance is good. It controls annual grasses and pigweed. The rate is 4 to 6 quarts of Ramrod 4L or 20 to 30 pounds of 20G per acre.

Banvel (dicamba) can be applied after planting until corn is no more than 5 inches tall. The addition of Banvel in approved combinations can improve control of broadleaf weeds without creating a risk of carryover injury the next year. Banvel may injure corn, especially if recommended rates are exceeded, applications are not accurate and uniform, or if corn is planted too shallow (less than 1½ inches). Do not use this treatment on coarse-textured soils or soils that are low in organic matter. The rate on fine-textured soils with over 2½ percent organic matter is 1 pint of Banvel.

Banvel is approved for use in combinations with Lasso, Dual, atrazine, Bladex, or Princep.

Prowl (pendimethalin) is registered for use only on corn after planting. Incorporation of Prowl may result in serious corn injury. Use only where it is possible to cover seed adequately with soil. Prowl can control annual grasses and pigweed and provides some control of smartweed and velvetleaf. You can improve broadleaf weed control by combining Prowl with atrazine, Bladex, or Banvel. Prowl plus atrazine or Bladex may be applied in the early postemergence period before grasses are in the two-leaf stage. These combinations may also help reduce the competition from wild proso millet. However, avoid postemergence application when corn is under stress from cool, wet weather; otherwise, corn injury may result. The rate for such combinations is 1 to 1½ quarts of Prowl 4E. Do not use Prowl plus Banvel on sandy soils or soils with less than 1½ percent organic matter.

Postemergence Herbicides

Lasso, Dual, Ramrod, or Prowl plus atrazine, or Lasso or Dual plus Banvel can be used on corn between the preemergence and very early postemergence stages (see preemergence section). To obtain satisfactory control, apply before grasses reach the two-leaf stage. For more information on postemergence principles, see section entitled "Postemergence Herbicide Principles."

Atrazine can be applied before grass weeds are more than 1½ inches high. Many annual broadleaf seedlings

are more susceptible than grass weeds and may be treated until they are up to 4 inches tall. For control of some broadleaf weeds, 1.2 pounds active ingredient of atrazine may be sufficient. This rate will generally need to be increased to 2 pounds for control of annual grass weeds.

The addition of oil-surfactant mixes or surfactants has generally increased the effectiveness of postemergence atrazine. Crop oil concentrates (80 percent oil and 20 percent surfactant) are used at the rate of 1 quart per acre. Surfactants are usually added at 0.5 percent of the total spray volume or at a rate of about 1 pint per acre. Results with the oil-surfactant mixes have generally been better than those with surfactants.

Applications of atrazine and oil sometimes damage corn that has been under stress from prolonged cold, wet weather or other factors. Do not use more than 2½ pounds of atrazine 80W, 2 quarts of atrazine 4L, or 2.2 pounds AAtrex Nine-O per acre if you mix with oil or oil concentrate. *Do not* add 2,4-D to the atrazine-oil treatment or severe injury may result. Mix the atrazine with water first and add the oil last. If atrazine is applied after June 10, do not plant any crop except corn or sorghum the next year.

Bladex (cyanazine) can be applied through the four-leaf stage of corn growth but before weeds exceed 1½ inches in height. The rate is 1½ to 2½ pounds of Bladex 80W per acre. *Do not use Bladex 4L* because it contains oil and can increase the potential for injury. Injury to corn may occur under cold, adverse growing conditions. The injury may only be temporary yellowing but can be more severe. Under drouthy conditions certain agricultural surfactants or vegetable oils may be added to Bladex 80W to improve weed control. Do not use petroleum crop oils or apply with liquid fertilizers for postemergence application. Do not apply Bladex postemergence on corn that is under severe stress.

One may combine Bladex 80W with atrazine 80W, substituting atrazine for 30 percent of the Bladex. A Bladex plus Banvel combination is also registered that allows for the addition of ½ to ⅔ pint per acre of Banvel; no surfactant or any type of oil should be added with this combination.

Banvel or Banvel II (dicamba) can be applied from emergence until corn is 36 inches tall or 15 days before tassel emergence, whichever comes first. Best results can be expected when using ½ to 1 pint of Banvel per acre when the corn is in the spike to 5-inch stage. Application at this time can offer several weeks of soil (residual) activity when the 1-pint rate is used. With this timing, crop tolerance is better than with preemergence treatments of Banvel. In addition, application rates can be higher than in the later postemergence treatment, and the likelihood of injury to nearby soybeans is diminished. For applications of Banvel II on corn from 5 to 36 inches tall, the preferred rate is 1 pint per acre. Banvel is labeled as an overlay (sequential) treatment following Sutan+, Eradicane, Lasso, Dual, Bicep, Ramrod, atrazine, Bladex, Princep, Roundup, Bronco, or paraquat.

Banvel is also labeled for postemergence use as a tank mix with atrazine, Bladex 80W, or 2,4-D. The postemergence rate for Banvel is ½ pint (¼ pound active ingredient per acre) after corn is 5 inches tall. The label allows for the addition of ⅛ to ¼ pound of 2,4-D acid equivalent per treated acre. With Banvel or Banvel plus 2,4-D, drop pipes should be used on the nozzles if corn is taller than 8 inches to help keep the spray off the corn leaves and out of the whorl.

For best results, use Banvel or Banvel II before June 20 with a spray volume of 20 gallons per acre and a spray pressure of no more than 20 psi to help reduce the risk to plants outside the target area.

To aid in the control of hemp dogbane, Banvel is approved for use at ½ pint with 1 pound acid equivalent per acre of 2,4-D LV ester or amine after corn is in the brown silk stage but at least 7 days before harvest.

2,4-D is effective in controlling many broadleaf weeds in corn. Use drop nozzles if corn is more than 8 inches high to decrease the possibility of injury. If you direct the nozzles toward the row, adjust the spray concentration so that excessive amounts are not applied to the corn.

Do not apply 2,4-D to corn from the tasseling to dough stage. After the hard dough to dent stage, you can apply 1 to 2 pints of certain 2,4-Ds by air or high clearance equipment to control some broadleaf weeds that may interfere with harvest or to suppress certain perennial weeds.

The suggested broadcast rate of acid equivalent per acre is ⅙ to ¼ pound of ester formulations or ½ pound of amine. This would be ⅓ to ½ pint of ester or 1 pint of amine for formulations with 4 pounds of 2,4-D acid equivalent per gallon.

The ester forms of 2,4-D can vaporize and injure nearby susceptible plants. This vapor movement is more likely with high-volatile than with low-volatile esters. Spray particles of either the ester or the amine form can drift and cause injury.

Corn is often brittle for 7 to 10 days after application of 2,4-D and thus is susceptible to stalk breakage from high winds or cultivation. Other symptoms of 2,4-D injury are stalk bending or lodging, abnormal brace roots, and failure of leaves to unroll.

High temperature and high humidity can increase the potential for 2,4-D injury, especially if corn is growing rapidly. If it is necessary to spray under these conditions, it may be wise to reduce the rate by about 25 percent. Corn hybrids differ in their sensitivity, and the probability of injury increases when corn is under stress.

Buctril or Brominal (bromoxynil) may be used to control broadleaf weeds in field and silage corn. It is important to treat when the weeds are small. For ground applications, use 20 gallons of water per acre, a spray pressure of 40 psi, and flat fan nozzles. Bromoxynil may cause some burning of corn leaves, but the effects are usually temporary.

Buctril 2E (at the rate of 1 to 1½ pints per acre) or

Brominal 4E (at ½ to 1 pint per acre) should be applied when corn is in the 2-leaf to 14-inch stage and before weeds are 4 to 6 inches tall. Use the higher rate on larger corn and weeds. Weeds controlled include cocklebur, lambsquarters, smartweeds, jimsonweeds, common and giant ragweed, tall and ivyleaf morningglory, and black nightshade. Pigweed and velvetleaf may require the higher rate if they are near the maximum labeled stage of growth. Bromoxynil may also help control small wild or bur cucumber. Bromoxynil is less likely than 2,4-D to cause drift injury or corn injury but offers less flexibility in time of application.

Bromoxynil is approved for use in combination with atrazine or 2,4-D. Rates are in the range of ½ to 1.2 pounds active ingredient per acre of atrazine or ¼ to ½ pound active ingredient per acre of 2,4-D. Refer to Buctril and Brominal labels for specific rates with each product. Do not add surfactant or crop oil. Do not add Bladex to bromoxynil.

Basagran (bentazon) is registered for postemergence use in corn in a manner similar to that for soybeans (see soybean section). Since corn is quite tolerant of Basagran, the addition of a crop oil concentrate is considered relatively safe. Basagran is also cleared at the rate of 1 to 1½ pints in combination with atrazine at 0.6 to 0.9 pound of 80W, 0.6 to 0.8 pound of 90WDG, or 1 to 1½ pints of 4L per acre. **Laddok** is a formulated mixture of Basagran plus atrazine. The rate is 2.4 to 3.6 pints per acre. Oil concentrate is added at 1 quart per acre for control of annual broadleaf weeds only. The combination is more economical than Basagran alone and will create less risk of carryover than atrazine alone.

Postemergence Soil-Applied Herbicides

Prowl, Treflan, or Lasso can be applied to the soil as a postemergence treatment. It may be necessary to use drop nozzles to avoid interference from corn leaves and ensure uniform application to the soil.

Prowl (pendimethalin) or Treflan (trifluralin) may be applied to the soil and incorporated after field corn is 4 inches high (for Prowl) or 8 inches high (for Treflan) and up to the time of the last cultivation. The field should be cultivated to control existing weeds and cover the roots at the base of the corn before application. The herbicide should then be thoroughly and uniformly incorporated into the top inch of the soil. Prowl may not need incorporation if irrigation or rainfall occurs soon after application. Prowl can be combined with atrazine.

These treatments may help control late-emerging grasses such as shattercane, wild proso millet, or fall panicum.

Lasso (alachlor) may be used alone or with atrazine as a soil-applied postemergence treatment to help control midseason annual grass weeds in corn that is grown for seed. Application should preferably be made after cultivation before weeds emerge and before the crop is 40 inches tall.

Directed Postemergence Herbicides

Directed sprays are sometimes needed for emergency situations, especially when grass weeds become too tall to be controlled by cultivation. However, weeds are often too large for directed sprays to be effective. Directed sprays cannot be used on small corn because a height difference between corn and weeds is needed to keep the spray off the corn. Corn leaves that come into contact with the spray can be killed, and injury may affect yields.

Lorox or Linex (linuron) may be applied as a directed spray after corn is at least 15 inches tall (free standing) but before weeds are 8 inches tall (preferably no more than 5 inches). Linuron controls broadleaf and grass weeds.

The broadcast rate is 1¼ to 3 pounds of Lorox 50W or 1¼ to 3 pints of 4L per acre, depending on weed size and soil type. Add Surfactant WK at the rate of 1 pint per 25 gallons of spray mixture. Cover the weeds with the spray, but keep it off the corn as much as possible. *Consider this an emergency treatment.*

Evik 80W (ametryn) is registered for directed use when corn is more than 12 inches tall and weeds are less than 6 inches tall. Evik should not be applied within 3 weeks of tasseling. The rate is 2 to 2½ pounds Evik 80W per acre (broadcast) plus 2 quarts of surfactant per 100 gallons of spray mixture. Extreme care is necessary to keep the spray from contacting the leaves. *Consider this an emergency treatment.*

Bladex 80W (cyanazine) or Bladex 80W plus atrazine may be used as a directed spray for lay-by treatment for *corn seed production fields* at least 60 days before harvest. Seed corn should be at least 10 inches tall and there should be a sufficient height difference between the corn and the weeds to allow the spray to cover the weeds but not touch the corn leaves. This treatment can control weeds that are up to 1½ inches tall and suppress weeds that are a little taller. The use of nitrogen solutions as carriers and/or the addition of crop oil or surfactant can enhance control. Do not apply over the top of corn.

Herbicides for Soybeans

Consider the kinds of weeds expected when you select a herbicide program for soybeans, especially when growing soybeans in narrow rows. The herbicide selectivity table (see last page of this guide) lists herbicides and their relative weed control ratings for various weeds.

Soybeans may be injured by some herbicides. However, they usually outgrow early injury with little or no effect on yield if stands have not been significantly reduced. Significant yield decreases can result when injury occurs during the bloom to pod fill stages. Excessively shallow planting may increase the risk of injury from some herbicides. Accurate rate selection for soil type is especially essential for Lorox, Lexone, and Sencor. Do not apply Lorox, Lexone, Sencor, or Modown after soybeans have begun to emerge. Follow label instructions as to rates, timing, incorporation, and restrictions. For registered combinations, see Table 3.

Preplant Herbicides

Incorporation is required for Treflan, Sonalan, Vernam, and Reward. Incorporation is optional for Amiben, Dual, Lasso, Modown, and Prowl when used alone and in some combinations. Dyanap, Lorox, and Surflan should not be incorporated.

Herbicides such as Dual and Surflan may be applied to the soil surface early preplant, but little if any postemergence activity on existing vegetation should be expected. Herbicides such as linuron and metribuzin can have some postemergence as well as residual activity, but the degree of postemergence activity can vary with factors such as temperature and humidity. Incorporation can improve performance if rainfall is limited and may increase the effectiveness of Dual or Lasso in controlling nutsedge. Incorporation should distribute the herbicide evenly in the top 1 to 3 inches of soil. Deep incorporation or very early application of the herbicide can cause significant reductions in weed control. For more information, see the section entitled "Herbicide Incorporation."

Table 3. — Registered Herbicide Combinations for Preplant Incorporated (PPI) or Preemergence (Pre) Use in Soybeans

	Amiben	Sencor or Lexone	Amiben + Sencor or Lexone	Lorox
PPI only				
Sonalan	1	1	—	—
Treflan	1	1	1	—
PPI or Pre				
Dual	1,2	1,2	1,2	2
Lasso	1,2	1,2	1,2	2
Prowl	1,2	1,2	1,2	2
Surflan*	2	2	—	2

1 = Preplant incorporated; 2 = preemergence.
— = Not registered.
* Not for preplant incorporation.

Dinitroaniline herbicides registered for weed control in soybeans are Treflan, Prowl, Sonalan, and Surflan. Treflan and Sonalan should be incorporated because they have low solubility and are subject to loss by vaporization and photodecomposition. Incorporation is optional with Prowl, but variable weed control and soybean injury may result if Prowl is not incorporated. Incorporation should distribute the herbicide uniformly in the top 2 to 3 inches of soil (see label for implement settings). Do not incorporate Surflan (see preemergence section).

The dinitroaniline herbicides control annual grasses, pigweed, and lambsquarters and may provide some control of smartweed and annual morningglory. Prowl and Surflan may also partially control velvetleaf. However, acceptable control of most other broadleaf weeds requires combinations or sequential treatments with other herbicides.

Soybeans are sometimes injured by dinitroaniline herbicides. Plants that have been injured by incorporated treatments may be stunted and have swollen hypocotyls and shortened lateral roots. Such injuries are not usually serious. Plants injured by preemergence applications may have stem calluses at the soil surface, which can cause lodging and yield loss.

Corn, sorghum, and small grains may be injured if they are grown after a soybean crop that has been treated with a dinitroaniline herbicide. The symptoms are poor germination and stunted, purple plants with poor root systems. To avoid carryover, use no more than the recommended rates and be sure that application and incorporation are uniform. The likelihood of carryover increases with double cropping or late application and after a cool, dry season. Adequate tillage may help dilute herbicide residue to help alleviate a carryover problem.

Treflan (**trifluralin**) can be applied alone anytime in the spring. Combinations with Sencor or Lexone should be applied no more than 2 weeks prior to planting, and combinations with Amiben, Furloe, or Modown should be applied within a few days prior to planting. Incorporate as soon as possible, but do not delay incorporation more than 24 hours (8 hours if soil is warm and moist). The rate is 1 to 2 pints of Treflan 4E or 10 to 20 pounds of Treflan 5G per acre. Treflan MTF is a multitemperature formulation that can be used to avoid problems associated with freezing in storage.

Sonalan (**ethalfluralin**) may be applied up to 3 weeks prior to planting and should be incorporated within 2 days after application. The rate for general weed control ranges from 1½ to 3 pints per acre, depending on soil texture. Sonalan may provide some control of nightshade at rates of 3 to 4½ pints per acre, but for this purpose it should be used in conjunction with Amiben, Dual, or Lasso or followed with Blazer. Sonalan is less likely to injure corn following soybeans than is Treflan. Sonalan may be tank-mixed with Ambien, Lasso, Dual, metribuzin, or Vernam.

Prowl (**pendimethalin**) can be applied within 60 days (alone) or 7 days (with Sencor or Lexone) prior to planting soybeans or applied after planting (see preemergence section). Preplant treatments should be incorporated within 7 days of application. Mechanical incorporation may not be necessary if adequate rainfall occurs. Rates are 1 to 3 pints of Prowl 4E per acre, although rates for combinations with Sencor or Lexone are lower than when the herbicide is used alone.

Sencor or Lexone (**metribuzin**) **plus Treflan, Sonalan, or Prowl** can be tank-mixed and applied within 7 to 14 days of planting. Incorporate uniformly into the top 2 inches of soil. The rate of Sencor or Lexone in these combinations is ½ to 1 pint of 4L or ⅓ to ⅔ pound of 75DF. Use the normal rate, or slightly less, of the dinitroaniline herbicide (see labels).

The application of Sencor or Lexone can also be split, one part being incorporated and the other part applied to the surface preemergence. This method requires two applications but can give better broadleaf control and less injury than incorporating the same total amount of Sencor or Lexone in a single application.

Amiben (chloramben) can be incorporated with Treflan, Sonalan, or Prowl. The rate is 4 to 6 quarts of Amiben 2S per acre. Amiben can also be applied and incorporated with Treflan or Prowl plus Sencor or Lexone as a three-way combination.

Vernam (vernolate) and **Reward 6E** (vernolate plus an extender) control annual grasses and pigweed. They sometimes provide fair control of annual morningglory, velvetleaf, and yellow nutsedge. Some soybean injury may occur in the form of delayed emergence, stunting, and leaf crinkling. Vernam can be applied within 10 days prior to planting and should be incorporated immediately. The broadcast rate is 2⅓ to 3½ pints of Vernam 7E or 20 to 30 pounds of Vernam 10G per acre. Vernam plus Treflan is labeled at the rate of 1 pint of Treflan plus 2⅓ to 3 pints of Vernam 7E per acre. The combination may reduce the risk of soybean injury, but it may also decrease control of velvetleaf and yellow nutsedge. Other labeled combinations include Vernam plus Amiben, Sonalan, Lasso, or Furloe.

Preplant or Preemergence Herbicides

Lasso (alachlor) or **Dual** (metolachlor) can be applied to soybeans and preplant incorporated or applied during the preemergence stage. Lasso may be applied within 1 week of planting. Dual may be applied to the soil surface early preplant up to 30 days before planting as a single treatment. Or a ⅔ rate can be used within 45 days of planting along with a ⅓ rate at planting. If rainfall is limited, incorporation can improve performance and increase yellow nutsedge control. Soybeans are quite tolerant of Lasso or Dual. The first to second trifoliate leaves often appear crinkled and have a drawstring effect on the middle leaflet, but these symptoms should not cause concern.

Lasso or Dual controls annual grasses and pigweed and can help control nutsedge and black nightshade. These herbicides can be combined with Lexone, Sencor, or Amiben (incorporated or preemergence) and with Lorox or Dyanap (preemergence only) to improve broadleaf weed control.

The rate for Lasso is 2 to 4 quarts Lasso 4E or 16 to 26 pounds of Lasso II 15G per acre. The rate for Dual 8E is 1½ to 3 pints per acre, and the rate for Dual 25G is 6 to 12 pounds per acre. Use the higher amount for the soil when incorporating or when black nightshade or yellow nutsedge are to be controlled. The rate for combinations is slightly less than that for the herbicide used alone (see labels). Lasso may be applied after soybean emergence but before soybeans pass the unifoliate stage.

Amiben (chloramben) can control annual grasses and many broadleaf weeds in soybeans when used at the full rate. Do not expect control of cocklebur or annual morningglory. Control of velvetleaf and jimsonweed is often erratic. Amiben occasionally injures soybeans, but damage does not usually affect yield. Injured plants may be stunted and have abnormal, shortened roots. If rain does not occur within 3 to 5 days of an Amiben preemergence application, you should rotary hoe. Amiben is best suited to soils that have over 2.5 percent organic matter.

Amiben can be applied alone or with Dual, Lasso, or Prowl as a preplant-incorporated or preemergence treatment. Amiben plus Sencor can also be mixed with Lasso, Dual, or Prowl as a preplant or preemergence treatment. Amiben can be applied as a preemergence treatment with Lorox, Lexone, or Sencor.

The Amiben broadcast rate alone is 20 to 30 pounds of 10G, 4 to 6 quarts of 2S, or 2.4 to 3.6 pounds of 75DS per acre. The Amiben rate in combinations is 3 to 6 quarts of 2S (1.8 to 3.6 pounds of 75DS) per acre. Use the higher rate where black nightshade, velvetleaf, or common ragweed is a problem weed.

Sencor or **Lexone** (metribuzin) can be applied anytime during the 1 to 2 weeks prior to planting and incorporated with Dual, Lasso, Prowl, or Treflan. Incorporation should distribute the herbicide evenly in the top 2 inches of soil. It can be applied preemergence by itself or with Amiben, Dual, Lasso, Prowl, Surflan, or Dyanap.

Sencor or Lexone can control many annual broadleaf weeds but cannot control annual morningglory. Control of giant ragweed, jimsonweed, and cocklebur is marginal at the reduced rates necessary to minimize soybean injury.

One symptom of soybean injury is yellowing (chlorosis) of the lower leaves at about the first trifoliate stage or later; it may be followed by browning of leaves and death of plants, depending upon the severity of the injury. Seedling diseases, weather stress, and atrazine carryover may increase the possibility of soybean injury. Injury may be greater on soils with a pH over 7.5. Accurate, uniform application and incorporation are essential. Some soybean varieties are more sensitive than others. Injury has sometimes occurred when organophosphate insecticides such as Thimet, Counter, Dyfonate, Lorsban, or Mocap were left in applicators used for corn planting and were applied to soybeans that were then being treated with metribuzin.

Adjust rates accurately according to soil conditions. *Do not apply to very sandy soil.* Combinations allow for reduced rates and thus reduce risk of soybean injury. The combination rate of Sencor or Lexone is ½ to 1 pint of 4L, or ⅓ to ⅔ pound of 75DF. You can use higher amounts as a split preplant and preemergence application. The higher amounts can improve broadleaf control but also increase the risk of soybean injury.

Modown (bifenox) can control pigweed, lambsquarters, and smartweed and can provide some control of velvetleaf. Modown 4F rates are 2½ to 4 pints per acre. Combinations with Dual, Lasso, or Surflan, or an overlay after Treflan can improve grass control. For preplant incorporation, the application should be made within 2 to 3 days of planting, and incorporation should distribute the herbicides uniformly in the top 1 inch of soil. Do not apply Modown after soybeans begin to emerge.

Soybeans may show stunting from Modown, especially from preemergence use followed by cold, wet soil condi-

tions during early growth stages. Injury symptoms are cupping and crinkling of the first few leaves. Soybean injury is usually not reflected in yield.

Furloe Chloro IPC (chlorpropham) can be preplant incorporated with Treflan or Vernam; or it can be applied preemergence by itself or with Lasso to improve smartweed control. Preplant application should be done within a few days of planting soybeans, and incorporation should distribute the herbicide uniformly in the top 1 to 2 inches of soil. The rate in sequential or tank mix combinations is 2 to 3 quarts of Furloe 4E per acre. Furloe 20G is used preemergence at 10 to 15 pounds per acre.

Preemergence Herbicides

Lorox or Linex (linuron) is best suited to silt loam soils that contain 1 to 3 percent organic matter. *Do not apply to very sandy soils.* Linuron controls broadleaf weeds better than grass weeds. It does not control annual morningglory, and control of cocklebur and jimsonweed is variable. Accurate and uniform application and proper rate selection are necessary to minimize the risk of crop injury. Tank mix combinations allow the use of a reduced rate of linuron to decrease the risk of soybean injury, but may also decrease the degree of weed control.

Linuron is registered in tank mix combinations with Amiben, Lasso, Dual, Prowl, or Surflan to improve grass control. The rate of linuron in these combinations is 1 to 1⅔ pounds of linuron 50W or 1 to 1⅔ pints of linuron 4L on silt loam soils that have less than 3 percent organic matter.

Surflan (oryzalin) can control annual grasses, pigweed, and lambsquarters if there is adequate rainfall. You should rotary hoe to control emerging weeds if adequate rain does not fall within 7 days after application. Surflan can be used for early preplant application for no-till soybeans. Do not use on soils that have more than 5 percent organic matter. The rate is 1 to 2 pounds per acre of Surflan 75W (¾ to 1½ quarts AS [aqueous suspension]) used alone or ⅔ to 1⅔ pounds of Surflan 75W in combinations. Surflan can be tank-mixed with Amiben, Lorox, Lexone, Sencor, or Dyanap to improve broadleaf weed control. Surflan may cause stem callusing, which can lead to soybean lodging. Do not allow Surflan to contact the soybean seed. For no-till soybeans, Surflan can be applied in fall or early spring over undisturbed stubble from the previous crop.

Prowl can be applied preemergence in combination with Amiben, Lorox, Lexone, or Sencor. When applied to the soil surface, Prowl may cause stem callusing, which can lead to soybean lodging. (See preplant section for more information.)

Dyanap (dinoseb plus naptalam) can be applied to soybeans from the time they are planted until the time the unifoliate leaves of the seedling unfold and expose the growing point. Tank mixes of Dyanap plus Lasso, Dual, or Surflan are registered to improve grass control. Dyanap can also be tank-mixed with Lasso 4E plus Sencor. The Dyanap rate is 4 to 6 quarts per acre for preemergence application.

Postemergence Herbicides

Research suggests that soybean yields will probably not be reduced if weeds are controlled within 3 to 4 weeks after planting. Postemergence herbicides are most effective when their use is part of a planned program and when they are applied while the weeds are young and tender. They should not be considered simply as emergency treatments. It is especially important to use timely treatments when using postemergence herbicides in narrow-row soybeans. Postemergence herbicides are often the best choice for controlling problem weeds such as cocklebur, annual morningglory, and volunteer corn. Registered combinations are shown in Table 4. For more information on conditions affecting application, see the section entitled "Postemergence Herbicide Principles."

Basagran (bentazon) can control many broadleaf weeds, such as cocklebur, jimsonweed, and velvetleaf. It is weak on pigweed, lambsquarters, and annual morningglory. It can be used for control of yellow nutsedge and Canada thistle but does not control annual grasses.

The suggested rate for Basagran is ¾ to 1 quart per acre, depending on the weed size and species. Application should be made when weeds are small (2-3 inches) and actively growing. These conditions usually exist when the soybeans are in the unifoliate to second trifoliate stage. Spraying during warm sunny weather can also improve performance. Do not spray if rain is expected within 8 hours. Use a minimum of 20 gallons of water per acre to get complete weed coverage. Adding a crop oil concentrate to Basagran may increase performance on most weeds but may cause some soybean injury. Morningglory that is up to 10 inches long can be controlled with the addition of 2 fluid ounces of 2,4-DB with Basagran. Do not add crop oil when mixing with 2,4-DB.

Blazer (acifluorfen) should be applied when broadleaf weeds are in the 2- to 4-inch stage and actively growing. Weeds controlled include annual morningglory, pigweed, jimsonweed, and black nightshade. Cocklebur and morningglory control can be improved with the addition of 2 fluid ounces of 2,4-DB. Apply the mixture when cocklebur and morningglory measure no more than 10 to 12 inches and soybeans have at least 5 trifoliate leaves.

The rate is 2 pints of Blazer 2L per acre. The Blazer 2L formulation does not include surfactant and requires the addition of a nonionic surfactant at a minimum of 1 pint per acre when used alone. The rate of surfactant may be increased to 2 to 4 pints per acre to improve control of small escaped grasses. Surfactant addition is not recommended when combining Blazer and 2,4-DB.

Since Blazer is a contact herbicide, leaf burn often occurs; however, the crop usually recovers within 2 to 3 weeks. For ground application, use 20 to 40 gallons of

Table 4. — Registered Postemergence Herbicide Combinations for Broadleaf Weed Control in Soybeans

	Amiben	Blazer	Butoxone*	Butyrac*
Alanap	X	—	X	X
Amiben		X	—	X
Basagran	—	X	—	X
Blazer	X		X	X
Dyanap	—	—	X	X

X = Registered.
— = Not registered.
* 2,4-DB.

water per acre applied with a minimum spray pressure of 40 psi. Do not spray if rain is expected within 6 hours. The herbicide Tackle is similar in active ingredient to Blazer 2L, and label clearance is pending.

A Basagran plus Blazer combination provides a means of broadening the spectrum of control. The rate is 1 to 2 pints of each product in the combination. Crop oil concentrate may be added. Refer to individual product labels for specifics.

Dyanap (dinoseb plus naptalam) at 2 quarts per acre can be applied to soybeans after the first trifoliate leaf is fully expanded until the soybeans become 20 inches tall. After 2 trifoliates are fully expanded, 3 quarts per acre may be used. Dyanap controls cocklebur, jimsonweed, and annual morningglory. A split application of 2 quarts at the first to second trifoliate stage, followed by 2 quarts 10 to 14 days later, is suggested for severe weed infestations. The addition of 2 fluid ounces per acre of 2,4-DB can improve control of some of the larger and more difficult weeds, especially if they are over 6 inches tall.

Best results are obtained by using high pressure (40 to 60 psi) and 8 to 10 gallons of water per acre. Use 5 gallons of water for aerial application. Although leaf burn can occur, the crop usually recovers within 2 to 3 weeks with little or no yield loss. Do not apply Dyanap to wet soybean foliage or if rain is expected within 6 hours. Do not add a surfactant or crop oil.

Amiben (chloramben) can be used for postemergence application on soybeans in the cracking to fourth trifoliate stage, but only within 33 days after planting. This treatment can be especially helpful in controlling velvetleaf, but smartweed, common ragweed, and pigweed may also be controlled or suppressed. Velvetleaf may be 1 to 8 inches tall and smartweed may be 1 to 3 inches tall. For ground applications, 10 to 20 gallons of water per acre, a spray pressure of 30 psi, and flat fan nozzle tips are suggested. The rate of Amiben 2S alone is 6 quarts; it is 5 to 6 quarts per acre in combination with either 2 to 3 fluid ounces of Butyrac 200, 2 to 3 quarts of Alanap, or 1½ to 2 pints of Blazer per acre. Crop oil concentrate should be used at 1 quart per acre with the Amiben alone or tank-mixed with Alanap. Do not add crop oil when tank-mixing with Butyrac. The Amiben plus Alanap or 2,4-DB should be applied when soybeans are in the third to sixth trifoliate stage. Apply the Amiben tank-mixed with Blazer at the appropriate rate for the weed size indicated on the Blazer label but within 33 days after planting. If Amiben is also soil-applied, do not use more than a total of 12 quarts per season.

Rescue (naptalam plus 2,4-DB) can be used for late-season postemergence control of cocklebur, giant ragweed, and wild sunflower; it may also suppress annual morningglory. Apply 2 to 3 quarts per acre after soybeans are about 18 inches tall or after first bloom. Use the lower rate when weeds are less than 12 inches tall. The addition of a crop oil concentrate or surfactant can improve control. Application before the weeds flower is suggested for best control. The water volume per acre is 10 to 25 gallons for ground application and a minimum of 5 gallons for aerial application. If rain occurs within 6 hours, effectiveness may be reduced. Activity may not be very noticeable until 10 to 14 days after application; maximum activity should occur 20 to 30 days after application. Crop injury such as leaf twisting and terminal droop may occur. To avoid possible yield losses, do not apply Rescue to soybeans under stress from drought, disease, or injury from another herbicide. *Do not apply Rescue within 60 days of harvest.*

Hoelon (diclofop-methyl) can control small annual grasses in the 1- to 4-leaf stage and volunteer corn. Let all the volunteer corn emerge, but apply Hoelon before the corn that emerged first is too large to obtain adequate spray coverage. For ground application, use a minimum of 20 gallons of water per acre and 40 psi spray pressure. For aerial application, use a minimum of 5 gallons of water per acre. The Hoelon rate for annual grasses, including volunteer corn, is 2 to 3⅓ pints. Crop oil concentrate can be added at 1 to 2 pints per acre. Do not tank-mix Hoelon with other postemergence herbicides. *Hoelon is a restricted-use herbicide.*

Poast (sethoxydim) can be used for postemergence control of annual and perennial grasses in soybeans. The rate is 1 pint per acre to control foxtails or panicums that are 3 to 8 inches tall or volunteer corn or shattercane that is 6 to 18 inches tall. One pint per acre can also control wirestem muhly when it is 6 inches tall. Johnsongrass and quackgrass require higher rates and may also need retreatment.

Use 10 to 20 gallons of spray volume per acre for ground application and a minimum of 5 gallons per acre for aerial application. Add crop oil concentrate at 2 pints per acre. Poast can be tank-mixed with Basagran, provided the Poast rate is increased by 50 percent. Sequential applications at least 24 hours apart may be more economical and practical, depending upon the weeds to be controlled and their size.

Fusilade (fluazifop-butyl) can be used for control of annual and perennial grass weeds in soybeans. The rate is ½ pint per acre when giant foxtail is 4 to 6 inches tall and other annual grasses are 2 to 4 inches tall. Use ¼ pint per acre when volunteer corn is 12 to 18 inches tall or shattercane is 6 to 12 inches tall. Fusilade can also control wirestem muhly, johnsongrass, and quackgrass.

The spray volume should be a minimum of 10 gallons per acre for ground application and 5 gallons per acre for aerial application. Add either crop oil concentrate at 1 percent by volume (1 gallon per 100 gallons of spray) or a nonionic surfactant at ¼ percent of spray volume. Apply before soybeans bloom. *Do not tank-mix Fusilade with other postemergence herbicides intended for control of broadleaf weeds except as specified.* A tank mix of Fusilade 4E and Blazer 2L is labeled for use without an increase in the Fusilade rate.

Roundup (glyphosate) can be applied through several types of selective applicators — recirculating sprayers, wipers, or rope wicks. This application is particularly useful for control of volunteer corn, shattercane, and johnsongrass. Roundup may also suppress hemp dogbane and common milkweed. Weeds should be at least 6 inches above the soybeans. Avoid contact with the crop. Equipment should be adjusted so that the lowest spray stream or wiper contact is at least 2 inches above the soybeans. For equipment calibration, refer to the Roundup label. For recirculating sprayers and wipers, use the rates given on the label. For rope-wick applicators, mix 1 gallon of Roundup in 2 gallons of water. A spot treatment with Roundup is also a good option in many fields.

Paraquat Harvest Aid

Paraquat and Gramoxone are registered for drying weeds in soybeans just before harvest. For indeterminate varieties (most Illinois varieties), apply when 65 percent of the seed pods have reached a mature brown color or when seed moisture is 30 percent or less. For determinate varieties, apply when at least one-half of the leaves have dropped and the rest of the leaves are turning yellow.

The rate is ½ to 1 pint of Paraquat or Gramoxone per acre. The higher rate is for cocklebur. The total spray volume per acre is 2 to 5 gallons for aerial application and 20 to 40 gallons for ground application. Add 1 quart of nonionic surfactant per 100 gallons of spray. Do not pasture livestock within 15 days of treatment, and remove livestock from treated fields at least 30 days before slaughter.

Herbicides for Sorghum

Atrazine may be used for weed control in sorghum (grain and forage types) or sorghum-sudan hybrids. Application may be made preemergence or postemergence. A preplant surface application may be made using a single application within 30 days of planting or a ⅔ plus ⅓ split application within 45 days of planting. Plant seed at least 1 inch deep. Do not use preplant or preemergence on soils with less than 1 percent organic matter. Incorporated treatments may cause injury if rainfall occurs prior to or shortly after sorghum emergence.

Injury may occur when sorghum is under stress from unusual soil or weather conditions or when rates are too high. The rate of application for preplant and preemergence is 2 to 3 pounds of atrazine 80W per acre. The postemergence rate is 2½ to 3¾ pounds 80W per acre without crop oil or 1.5 pounds 80W with crop oil or crop oil concentrate. For the 4L or 90 percent dry flowable formulations, rates are approximately equivalent to these on an active ingredient basis. Rotational crop recommendations and weed control are the same as for atrazine used in corn. Failure to control fall panicum has been a major problem.

Milogard (propazine) is better tolerated by sorghum than is atrazine, but grass control is not as good. Only corn or sorghum may be planted in rotation within 12 months after treatment.

Ramrod (propachlor) may be used alone or in combination with atrazine, Milogard, Bladex, or Modown for sorghum. Ramrod can improve grass control, but rates must not be skimpy, especially on soils that are relatively low in organic matter. For specific rates, consult the label.

Lasso (alachlor) may be preplant incorporated or used preemergence for grain sorghum if seed is satisfactorily treated with the seed protectant Screen (flurazole). This use also applies to certain other products containing alachlor.

Dual (metolachlor) or Dual plus atrazine (Bicep) can be used for sorghum if seed has had the Concep-seed treatment. These herbicides will control grasses better than will atrazine applied alone. An early preplant treatment of Dual or Bicep may be used in a similar manner as for corn, but Concep-treated seed should still be used.

2,4-D may be applied postemergence for broadleaf control in 4- to 24-inch-tall sorghum. Use drop pines on nozzles if sorghum is more than 8 inches tall. Rates are similar to those for use in corn (see section on corn herbicides).

Banvel can be applied preplant to emerged and actively growing weeds up to 15 days before planting. It may be applied postemergence to sorghum that is between the 3-leaf and 15-inch stage. The 3- to 5-leaf stage is preferred. The rate is ½ pint per acre. Do not graze or feed treated forage or silage prior to the mature grain stage. Sorghum may be injured by Banvel.

Brominal (bromoxynil) is registered for control of broadleaf weeds in grain sorghum that is up to 14 inches tall and before weeds are 4 inches tall. It is generally safer than 2,4-D on grain sorghum.

Prowl (pendimethalin) may be applied to grain sorghum from the 4-inch growth stage to as late as the last cultivation primarily for control of late-season annual grass weeds. See the section entitled "Herbicides for Corn," subsection on postemergence soil-applied herbicides, for more information.

Bronco (glyphosate plus alachlor) may be used alone or with atrazine where grain sorghum is to be planted directly into a cover crop or in previous crop residue. It can control emerged annual weeds and suppress many

emerged perennial weeds, as well as give preemergence control. As with Lasso, grain sorghum seed must be treated with Screen.

Paraquat may be used for control of annual weeds where grain sorghum is to be planted into previous crop residues.

Specific Weed Problems

Yellow Nutsedge

Yellow nutsedge is a perennial sedge with a triangular stem. It reproduces mainly by tubers. Regardless of the soil depth at which the tuber germinates, a basal bulb develops 1 to 2 inches under the soil surface. A complex system of rhizomes (underground stems) and tubers develops from this basal bulb. Yellow nutsedge tubers begin sprouting about May 1 in central Illinois. For the most effective control, soil-applied herbicides should be incorporated into the same soil layer in which this basal bulb is developing.

For soybeans, a delay in planting until late May allows time for two or three tillage operations to destroy many nutsedge sprouts. These operations help deplete food reserves in nutsedge tubers. Row cultivation is helpful. Preplant applications of Lasso, Dual, Vernam, or Reward will also help.

Lasso (alachlor) preplant incorporated at relatively high rates can often give good control of nutsedge.

Dual (metolachlor) can be applied at 2 to 3 pints of 8E per acre to control nutsedge. Preplant incorporated treatment is preferred to treatment at the preemergence stage.

Vernam 7E (vernolate) applied preplant at 3½ pints per acre is also effective against yellow nutsedge. Reward 6E is an alternative to Vernam. Immediate incorporation is necessary with Vernam or Reward.

Basagran (bentazon) applied postemergence can also help control nutsedge in soybeans. When nutsedge is 6 to 8 inches tall, ¾ to 1 quart per acre can be applied. If needed, a second application can be made 7 to 10 days later. The addition of a crop oil concentrate to Basagran may improve performance.

For corn that is planted relatively early, preplant tillage before nutsedge sprouts is of little help in control. Timely cultivation gives some control, but a program of herbicides plus cultivation has provided the most effective control of nutsedge.

Several preplant treatments are available. Eradicane Extra at 2⅔ to 4 quarts or Sutan+ or Genate Plus at 4¾ to 7⅓ pints per acre are effective for control of yellow nutsedge in corn. They must be incorporated immediately. Lasso or Dual applied in corn as for soybeans can also be quite effective.

The combinations of Lasso, Dual, Sutan+, Genate Plus or Eradicane incorporated with atrazine may improve control of nutsedge while also controlling broadleaf weeds.

Atrazine or Bladex (cyanazine) is used as a postemergence spray to control emerged yellow nutsedge when it is small. Split applications of atrazine plus oil have been more effective than single applications. Basagran can be used in corn in a manner similar to that for soybeans. Lorox (linuron) directed postemergence spray has also given some control.

Johnsongrass

Johnsongrass can reproduce both from seeds and by rhizomes. Both chemical and cultural methods are needed to control johnsongrass rhizomes.

Much of the rhizome growth occurs after the johnsongrass head begins to appear. Mowing, grazing, or cultivating to keep the grass less than 12 inches tall can reduce rhizome production significantly.

Control of johnsongrass can also be improved with tillage. Fall plowing and disking bring the rhizomes to the soil surface, where many of them are winter-killed. Disking also cuts the rhizomes into small pieces, making them more susceptible to chemical control.

Johnsongrass rhizomes can be controlled or suppressed with the use of certain herbicides in various cropping programs. Several preplant-incorporated herbicides can provide control of johnsongrass seedlings in soybeans or corn (see the table at the end of this publication).

Treflan (trifluralin) or Prowl (pendimethalin) used in a 3-year soybean program has been fairly successful in controlling rhizome johnsongrass. They are used at 1½ to 2 times the normal rate each year for 2 years; in the third year, either they are used at the normal rate, or another suitable herbicide is used before a regular cropping sequence is resumed. Thorough preplant tillage and incorporation are necessary for satisfactory control. Be certain not to plant crops such as corn or sorghum the year following application of these herbicides at the higher rates.

Fusilade (fluazifop-butyl) can control johnsongrass in soybeans. Apply ½ pint per acre when the weed is 12 to 18 inches tall. If regrowth occurs, apply ⅜ pint when johnsongrass is 6 to 12 inches. Always add crop oil concentrate at 1 percent of volume or nonionic surfactant at 0.25 percent of volume.

Poast (sethoxydim) can control johnsongrass in soybeans. Apply 1½ pints plus 1 quart crop oil concentrate per acre when the johnsongrass is 15 to 20 inches tall. If regrowth occurs, apply 1 pint per acre when the johnsongrass is 6 to 10 inches.

Eradicane Extra can help control rhizome johnsongrass in corn when used at a rate of 4 quarts per acre with a tillage program; or Eradicane 6.7E can be used at 7⅓ pints per acre.

Roundup (glyphosate) can be used as a spot treatment to control johnsongrass in corn, soybeans, or sorghum. Apply a 1 percent solution when johnsongrass has reached the boot to head stage and is actively growing. Use of Roundup in wick or recovery-type sprayers is effective for control of johnsongrass in soybeans. (See section on postemergence herbicides for soybeans.)

Roundup may be applied in small grain stubble when johnsongrass is in the early head stage. Fall applications should be made before the first frost. At least 7 days should be allowed after treatment before tillage.

Quackgrass

Quackgrass is a perennial grass with shallow rhizomes. It is found primarily in the northern part of Illinois.

Atrazine is quite effective when used as a split application in corn. Apply 2½ pounds of atrazine 80W per acre in the fall or spring and plow 1 to 3 weeks later. Another 2½ pounds per acre should be applied as a preplant or preemergence treatment. Postemergence application is usually less effective. A single treatment with 3¾ to 5 pounds per acre can be applied either in the spring or fall 1 to 3 weeks before plowing, but the split application usually gives better control of annual weeds. If more than 3 pounds of atrazine is applied per acre, plant no crops other than corn or sorghum the next year.

Eradicane Extra can be used to suppress quackgrass in corn where more flexibility in cropping sequence is desired. A rate of 2⅔ quarts per acre of Eradicane Extra can be used on light infestations, while 4 quarts per acre is suggested for heavier infestations. There is some risk of corn injury, especially at the higher rate. A tank mix with atrazine should improve control. If Eradicane 6.7E is used, the rate should range from 4¾ to 7⅓ pints per acre.

Fusilade (fluazifop-butyl) may be used for quackgrass control in soybeans at ½ pint per acre. Apply when quackgrass has 3 to 5 leaves and before it is 10 inches tall. If regrowth occurs, a second application of ½ pint per acre may be made. Always add crop oil concentrate or nonionic surfactant to Fusilade.

Poast (sethoxydim) can be applied in soybeans at the rate of 2½ pints plus 1 quart of crop oil concentrate per acre when quackgrass is 6 to 8 inches tall. If regrowth occurs, apply 1½ pints per acre when the quackgrass is 6 to 8 inches high.

Roundup (glyphosate) can be used for controlling quackgrass before planting either corn or soybeans. Apply 1 to 3 quarts per acre when quackgrass is 8 inches tall and actively growing (fall or spring). Delay tillage for 3 or more days after application.

Canada Thistle

Canada thistle is a perennial weed that has large food reserves in its root system. There are several varieties of Canada thistle. They differ not only in appearance but also in their susceptibility to herbicides.

2,4-D may give fairly good control of some strains. Rates will depend on where the thistle is growing. For example, higher rates can be used in grass pastures or in noncrop areas than can be used in corn.

Banvel (dicamba) often is a little more effective than 2,4-D and may be used alone or in combination with 2,4-D. Banvel can be used as an after-harvest treatment in wheat, corn, or soybean fields or in fallow fields. Rates vary from 1 to 2 quarts of Banvel alone or in tank-mix combinations with 2,4-D or Roundup. Fall treatments should be applied before killing frosts. For best results thistles should be fully emerged and actively growing. Fields treated in the fall with Banvel may be planted to corn, sorghum, or wheat the next season.

Atrazine and oil applied postemergence has been fairly effective in controlling Canada thistle in corn. Make the application before thistles are 6 inches tall.

Basagran (bentazon) can be used for control of Canada thistle in soybeans or corn when the thistles are 8 to 12 inches tall. Apply ¾ to 1 quart per acre in a single application, or for better control make two applications of ¾ to 1 quart per acre each, 7 to 10 days apart.

Roundup (glyphosate) can be used at 2 to 3 quarts per acre when Canada thistle is at or beyond the early bud stage. Fall treatments must be applied before frost for best results. Allow 3 or more days after application before tillage.

Black Nightshade

Black nightshade is an annual weed that has become an increasing problem for Illinois soybean growers. The principal problem is caused by the berries, which are about the same size as soybeans at harvest. They contain a sticky juice that can gum up a combine.

Black nightshade does not present much of a problem in corn but should be controlled nonetheless to help reduce production of the weed's seed. Herbicides such as atrazine, Bladex, Banvel, Lasso, and Dual are helpful for controlling this weed in corn.

It can be helpful to plant suspect fields to corn rather than to soybeans. If soybeans must be planted, plant suspect fields last. This strategy helps control the midseason flush by making the full strength of the herbicide last longer. Preemergence applications usually maintain control longer than those that are preplant incorporated.

For control in soybeans, Lasso, Dual, Amiben, or linuron at full rates or a combination of Amiben or linuron with Lasso or Dual is helpful. Suspect fields should be monitored and a postemergence application of Blazer considered. Blazer 2L at 2 pints per acre can control nightshade when applied at the 2- to 4-leaf stage. The addition of a surfactant or crop oil to Blazer 2L is recommended when nightshade is beyond the 3-leaf stage.

Harvest-aid sprays generally do not solve the problem because they do not make the berries fall before the soybeans are harvested.

Additional Information

Not all herbicides and herbicide combinations available are mentioned in this publication. Some are relatively new and are still being tested. Some are not considered to be well adapted to Illinois or are not used very extensively. For further information on field crop weed control, consult your county extension adviser or write to the Department of Agronomy, N-305 Turner Hall, 1102 S. Goodwin Avenue, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801.

Relative Effectiveness of Herbicides on Major Weeds

This chart gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Type of soil is also a very important factor to consider when selecting herbicides. Rate of herbicide used also will influence results. G = good, F = fair or variable, and P = poor.

	Grasses								Broadleaf Weeds										
	Crop tolerance	Foxtail	Barnyardgrass	Crabgrass	Fall panicum	Johnsongrass seedlings or Shattercane	Volunteer corn	Yellow nutsedge	Annual morningglory	Cocklebur	Jimsonweed	Lambsquarters	Nightshade, black	Pigweed	Ragweed, common	Ragweed, giant	Smartweed	Sunflower, wild	Velvetleaf
OYBEANS																			
replant																			
Treflan, Sonalan	F-G	G	G	G	G	G	F	P	P-F	P	P	G	P-F	G	P	P	P-F	P	P
Sencor, Lexone + dinitroaniline	F	G	G	G	G	G	F	P	F	F	F-G	G	P	G	G	F	G	F	F-G
Vernam, Reward	F	G	G	G	G	G	P-F	F	P-F	P	P	F	P	G	P	P	P	P	F
replant or Preemergence																			
Amiben	F-G	G	F-G	F-G	F-G	F	P	P	P	P	P-F	G	F-G	G	F-G	F	F-G	P	F
Lasso, Dual	G	G	G	G	G	P-F	P	F-G	P	P	P	F	F-G	G	P-F	P	P-F	P	P
Lasso or Dual + Sencor or Lexone	F	G	G	G	G	P	P	F	P	F	F-G	G	F-G	G	F	F	G	F	F-G
Lasso or Dual + Lorox,[1] Linex[1]	F	G	G	G	G	P	P	P-F	P	F	F	G	F-G	G	G	F	G	F	F-G
Lorox,[1] Linex[1]	F	F	F	F	F	P	P	P	P	F	F	G	F	G	G	F	G	F	F-G
encor, Lexone	F	F	F	F	F	P	P	P	P	F	F-G	G	P	G	G	F	G	F	F-G
urflan,[1] Prowl	F-G	G	G	G	G	G	F	P	P-F	P	P	G	P	G	P	P	P-F	P	P-F
ostemergence																			
Basagran	F-G	P	P	P	P	P	P	F	P-F	G	G	F-P	P	P	F	F	G	G	F-G
Blazer	F	P-F	P	P-F	P	P	P	P	F-G	F	G	F-P	F-G	G	F	G	G	F	P
Dyanap	F	P	P	P	P	P	P	P	F-G	G	G	F	P-F	F	F	F	P-F	F	P
2,4-DB	P-F	P	P	P	P	P	P	P	F-G	G	P-F	F	P	F	F	F	P	F	P
Hoelon	G	G	G	P-F	F	P	G	P	P	P	P	P	P	P	P	P	P	P	P
oast, Fusilade	G	G	G	G	G	G	G	P	P	P	P	P	P	P	P	P	P	P	P
Rescue	F-G	P	P	P	P	P	P	P	F	G	F	P-F	P	F-G	P	G	P	G	P
ORN																			
replant																			
utylate, EPTC	F-G	G	G	G	G	F-G		F-G	P	P	P	P-F	F	G	P	P	P	P	F
utylate, EPTC + atrazine, Bladex	F-G	G	G	G	G	F-G		F-G	F-G	F-G	G	G	G	G	G	F	G	F-G	F-G
rincep + atrazine	G	F-G	F-G	F	F	P-F		P	F-G	F-G	G	G	G	G	G	G	G	G	F
replant or Preemergence																			
trazine	G	F-G	F	P	P	P		F	G	F-G	G	G	G	G	G	G	G	G	F-G
ladex	F-G	F-G	F-G	F-G	G	P		P	F	F-G	G	G	G	F	G	F-G	G	F-G	F-G
ladex + atrazine	F-G	F-G	F	F	F-G	P		P	F-G	F-G	G	G	G	G	G	F-G	G	F-G	F-G
asso, Dual	F-G	G	G	G	G	P-F		F-G	P	P	P	F	F-G	G	P-F	P	P-F	P	P
asso or Dual + atrazine or Bladex	F-G	G	G	G	G	P		F-G	F-G	F	G	G	G	G	G	F	G	F-G	F
rowl + atrazine or Bladex[1]	F	G	G	G	G	F		P	F-G	F	G	G	G	G	G	F	G	F-G	F-G
amrod[1]	G	G	F	F-G	F	P		P-F	P	P	P	F	P	G	P	P	P	P	P
stemergence																			
trazine + oil	F-G	F-G	G	P	P	P		F	G	G	G	G	G	G	G	F	G	G	G
anvel	F-G	P	P	P	P	P		P	G	G	G	G	G	G	G	G	G	G	F
asagran	G	P	P	P	P	P		F	P-F	G	G	F-P	P	P	F	F	G	G	F-G
ladex	F-G	G	G	F	F-G	P		F	F	F-G	G	F	G	F-G	G	F	G	F	F-G
uctril, Brominal	F-G	P	P	P	P	P		P	G	G	G	G	G	F	G	F	G	F-G	F
,4-D	F	P	P	P	P	P		P	G	G	F	G	F	G	G	G	P-F	G	F-G

Do not use for preplant incorporation.

WEED CONTROL IN SMALL GRAINS, PASTURES, AND FORAGES

Good weed control is essential for maximum production of high quality small grains, pastures, and forages in Illinois. When properly established, crops can usually compete effectively with weeds; herbicides may therefore be unnecessary. In some instances, however, weeds do become major problems that warrant control. For example, wild garlic is considered the worst weed problem in wheat in southern Illinois. Having a life cycle similar to winter wheat, wild garlic can establish itself with the wheat, grow to maturity, and produce large quantities of bulblets by wheat harvest time.

In pastures, brush species and thistles can often become troublesome. Annual grasses and broadleaf weeds such as chickweed and henbit may cause problems in hay crops. Through proper management, many of these weed problems can be effectively managed, if not avoided.

Small Grains

Good weed control is critical for maximum production of high quality small grains. Many weed problems can be dealt with before the establishment of oats or wheat. For example, wild garlic can be controlled in the late fall after corn or soybean harvest. When the weeds are actively growing, spray them with 2 to 3 quarts per acre of 2,4-D ester (4 pounds a.i.) on warm days.

Tillage is another method of controlling weeds. Although generally limited to preplant and postharvest operations, tillage can destroy many annual weeds and help suppress certain perennials. Good cultural practices such as proper seeding rate, optimum soil fertility, and timely planting will help establish the crop and make it more competitive with weeds.

If annual broadleaf weeds become a problem later on, the judicious use of recommended herbicides may be needed. Postemergence herbicides such as 2,4-D, MCPA, dicamba, and bromoxynil can provide relatively good control of susceptible species (see Table 1*). However, most perennial broadleaf weeds cannot be controlled satisfactorily at the low herbicide rates used in small grains; higher rates are undesirable because they can cause serious crop injury. To control perennial weeds, translocated herbicides such as 2,4-D, dicamba, or glyphosate (Roundup) should be used in combination with tillage before establishing small grains.

A decision to use postemergence herbicides for broadleaf weed control in small grains should be based on several considerations:

1. *Nature of the weed problem.* Identify the species present and rank the severity of the infestation. Also note the size of the weeds. Weeds are usually best controlled while quite small.
2. *Stage of the crop.* Most herbicides are applied after full tiller until the boot stage. Don't apply herbicides from the boot stage up to the hard dough stage of most small grains. (Boot stage refers to the period when head formation causes the sheath to swell.)
3. *Presence of a legume underseeding.* Usually 2,4-D ester formulations and certain other herbicides listed in Table 2 should not be applied because they may damage the legume underseeding.
4. *Herbicide activity.* Determine crop tolerance and weed susceptibility to herbicides by referring to Tables 1 and 2. Use the lower rates in Table 2 on the more easily controlled weeds and the higher rates on the more difficult species. Tank mixes may broaden the weed spectrum and thereby improve control; check the herbicide label for registered combinations.
5. *Economic justification.* Consider cost of the treatment in terms of potential benefits such as value of increased yield, improved quality of grain, and ease of harvesting the crop.

Table 2 outlines current suggestions for weed control options in wheat and oats, the two most commonly grown small grains in Illinois. Always consult the herbicide label for specific information about the use of a given product.

* Table numbers 1 through 6 refer to the tables in this section only.

Grass Pastures

Unless properly managed, broadleaf weeds can become serious in grass pastures. They can compete directly with forage grasses and reduce the nutritional value and longevity of the pasture. Certain species such as white snakeroot and poison hemlock are poisonous to livestock.

Perennial weeds are probably of greatest concern. They can exist for many years, reproducing both from underground parent rootstocks and from seed. While occasional mowing or grazing helps control certain annuals, perennials can grow back from underground root reserves.

Certain biennials can also flourish in grass pastures. The first year, they exist as a prostrate rosette, so even close mowing does little to control their growth. The second year, biennials produce a seedstalk and a deep taproot. If grazed or mowed at this stage, root reserves can sometimes allow the plant to grow again, thereby increasing its chances of surviving to maturity.

In general, the use of good cultural practices such as optimum soil fertility, rotational grazing, and periodic mowing can help keep grass pastures in good condition and more competitive with weeds. However, where weeds become troublesome, 2,4-D or Banvel can be used; Tordon and Roundup can also be used as spot treatments.

Proper identification of the target weed species is important. As shown in Table 3, weed species vary in their susceptibility to different herbicides. Timing of application of a herbicide may also affect the degree of weed control. Annuals and biennials are most easily controlled while young and relatively small. A fall or early spring treatment may be called for if biennials or winter annuals are the main weed problem. Consider a spring or early summer treatment for summer annuals. To control established perennials, apply herbicides when weeds are in the bud to bloom stage. Perennials are most susceptible at this time because food reserves are moving back into the roots.

Spray woody brush species after they are fully leafed out and actively growing. Where regrowth occurs, a second treatment may be needed in the fall. During the dormant season, oil-soluble forms of 2,4-D or Banvel can be used in fuel oil.

The weed control options in grass pastures are shown in Table 4. Always consult the herbicide label for specific information about the use of a given product.

Forage Legumes

Weed control is very important in the management of forage legumes. Weeds can severely reduce the vigor of legume stands and thus cause losses in yield and forage quality. Good management begins with weed control practices that prevent weeds from becoming serious problems.

To minimize problems, prepare the seedbed properly so that it is clean and firm, and select an appropriate legume variety. If you use high quality seed and follow the recommendations for liming and fertility, the legume crop may vigorously crowd out many weeds and reduce the need for herbicides.

In fields where companion crops such as oats are used to reduce weed competition, seed at about half the rate for grain production to ensure that the legumes will become established without undue stress. If the legume is seeded without a companion crop (direct seeded), the use of an appropriate herbicide is suggested.

Balan and Eptam or Genep are registered for preplant incorporation for legumes that are not seeded with grass or small grain companion crops. These herbicides will control most grasses and some broadleaf weeds. In fall plantings, the weeds controlled include winter annuals such as downy bromegrass and cheat. In spring legume plantings, the summer annual weeds controlled include foxtails, pigweeds, lambsquarters, crabgrass, and fall panicum.

Eptam or Genep may also help suppress johnsongrass seedlings, yellow nutsedge, and shattercane, but will not effectively control mustards, smartweed, or established perennials. Balan and Eptam or Genep need to be thoroughly incorporated soon after application to prevent herbicide loss. They should be applied shortly before the legume is seeded so that they will remain effective as long as possible into the growing season.

Weeds that emerge during crop establishment should be evaluated for their potential to become problems. If they do not reduce the nutritional value of the forage or if they can be controlled by mowing, they should not be the primary target of postemergence herbicides. Winter annual weeds, for instance, do not compete vigorously with the crop after the first spring cutting. Unless these weeds are unusually dense or weed seed production becomes a concern, they may not be a significant problem. Some weeds such as dandelions are palatable and may not need to be controlled if the overall legume stand is dense and healthy. However, undesirable weeds must be controlled early to prevent their establishment.

Table 5 outlines current suggestions for weed control options in legume forages. The degree of control will often vary with weed size, application rate, and environmental conditions. Be sure to select the correct postemergence herbicide for the specific weeds to be controlled (see Table 6). Always consult the herbicide label for specific information about the use of a given product.

Table 1. — Effectiveness of Herbicides on Weeds in Small Grains

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, and P = poor.

Weed	Life cycle	Susceptibility to herbicide			
		2,4-D (many)	MCPA (many)	Dicamba (Banvel)	Bromoxynil (Buctril, Brominal)
Dandelion	perennial	F	F	E	P
Horseweed (marestail)	annual	F	F	E	F
Lambsquarters, common	annual	E	E	E	G
Mustard, wild	annual	E	E	F	F
Nightshade, eastern black	annual	F	F	G	G
Pennycress, field	annual	E	E	F	F
Pigweed spp.	annual	E	E	E	F
Ragweed, common	annual	E	F	E	F
Ragweed, giant	annual	E	F	E	F
Shepherdspurse	annual	G	G	F	F
Smartweed	annual	G	F	E	G
Velvetleaf	annual	G	G	F	E
Wild buckwheat	annual	F	F	E	G
Wild garlic	perennial	G	F	P	P
Wild lettuce	annual	E	G	E	F

Table 2. — Weed Control in Small Grains

Herbicide	Broadcast rate/acre	Remarks	Restrictions
OATS AND WHEAT			
2,4-D, 4 lb a.i. (amine)	½ to 1½ pt	Winter wheat more tolerant than oats. Apply in spring after full tiller but before boot stage. Do not treat in fall. Use lower rate of amine if underseeded with legume. Some legume damage may occur. May be used as preharvest treatment at 1 to 2 pints per acre during hard dough stage.	Do not forage or graze within 2 weeks after treatment. Do not feed treated straw to livestock.
MCPA (amine)	¼ to 3 pt	Less likely than 2,4-D to damage oats and legume underseeding. Apply from 3-leaf stage up to boot stage. Rate varies with crop and weed size and presence of legume underseeding.	Do not graze dairy animals on treated areas for 7 days after treatment.
Banvel, 4 lb a.i. Banvel II, 2 lb a.i.	4 fl oz 8 fl oz	Do not apply to small grains with legume underseeding. In fall-seeded wheat, apply before jointing stage. In spring-seeded oats, apply before oats exceed 5-leaf stage.	Do not graze or harvest for dairy feed before ensilage (milk) stage.
Bromoxynil (Buctril 2E or Brominal ME4)	 1½ to 2 pt ½ to 1 pt	Do not apply to small grains with legume underseeding. Apply bromoxynil alone to fall-seeded small grains in the fall or spring but before the boot stage. In spring-seeded oats apply from the one-leaf stage up to the boot stage. Weeds are best controlled before they are past the 3- to 4-leaf stage or less than 1½ inches across if rosettes.	Do not graze treated fields for 30 days after application.
WHEAT ONLY			
2,4-D, 4 lb a.i. (ester)	½ to ¾ pt	Do not apply to wheat with legume underseeding. Apply in spring after full tiller but before boot stage. For preharvest treatment apply 1 to 2 pints per acre during hard dough stage. For control of wild garlic or wild onion apply 1 to 2 pints in the spring when wheat is 4 to 8 inches high after tillering but before jointing. These rates may injure the crop.	Do not forage or graze within 2 weeks after treatment. Do not feed treated straw to livestock.

Table 3. — Effectiveness of Herbicides on Weeds in Grass Pastures

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, P = poor, and N = none.

Weed	Life cycle	Susceptibility to herbicide			
		2,4-D (many)	Dicamba (Banvel)	Picloram (Tordon)	Glyphosate (Roundup)
Burdock, common	biennial	E	E	E	G
Daisy, oxeye	perennial	F	E	E	G
Dandelion	perennial	E	E	E	G
Dock, curly	perennial	P-F	E	E	G
Goldenrod spp.	perennial	F	G	E	E
Horseweed (marestail)	annual	F	E	E	E
Ironweed	perennial	F	G	E	E
Milkweed, common	perennial	P	F	G	F
Multiflora rose	perennial	F	G	G	G
Nettle, stinging	perennial	G	G	G	G
Pennycress, field	annual	E	E	E	E
Plantain spp.	perennial	E	G	E	G
Poison hemlock	biennial	G	E	E	G
Ragweed, common	annual	E	E	E	E
Ragweed, giant	annual	E	E	E	E
Snakeroot, white	perennial	F	G	G	G
Sorrel, red	perennial	N	E	E	E
Sowthistle	perennial	F	G	G	G
Thistle, bull	biennial	E	E	E	E
Thistle, Canada	perennial	F	E	E	G
Thistle, musk	biennial	E	G	E	E
Water hemlock, spotted	perennial	G	E	E	G

Table 4. — Broadleaf Weed Control in Grass Pastures

Herbicide	Rate/acre	Remarks	Restrictions
2,4-D, 4 lb a.i. (amine or low volatile ester)	2 to 4 pt	Broadleaf weeds should be actively growing. Higher rates may be needed for less susceptible weeds and some perennials. Spray bull or musk thistles in the rosette stage (spring or fall) while actively growing. Spray perennials such as Canada thistle in the bud stage. Spray susceptible woody species in spring when leaves are fully expanded.	Do not graze dairy animals within 7 days after treatment. Do not apply to newly seeded areas or after heading begins. Do not apply to grass when in boot to milk stage.
Banvel, 4 lb a.i. Banvel II, 2 lb a.i. (double the rate shown at right)	Annuals: ½ to 1½ pt Biennials: ½ to 3 pt Perennials: 1 to 2 pt (suppression) Perennials: 1 to 6 qt (control) Woody brush: 1 to 2 pt (suppression) Woody brush: 1 to 8 qt (control)	Use lower rates for susceptible annuals when small and actively growing and for susceptible biennials in the early rosette stage. Use higher rates for larger weeds, for less susceptible weeds, for established perennials in dense stands, and for certain woody brush species.	Refer to label for specific timing restrictions for lactating dairy animals. Remove meat animals from treated areas 30 days before slaughter.
Tordon 10K (picloram)	40 lb/acre or 1 lb/1,000 sq ft or 1½ oz/100 sq ft	Apply to soil for control of undesirable woody plants such as multiflora rose, hawthorn, juniper, sumac. Applications are best made in spring or early summer or during times of rapid growth. Apply to individual plants and clumps or to larger, dense infestations. Spread uniformly over plant root areas. Will not be effective until it rains. More than one treatment may be needed. Injury or suppression of certain grasses such as smooth bromegrass may occur. May kill or injure desirable forbs, trees, or shrubs from root uptake.	A restricted-use pesticide. Limit coverage to 25% of an applicator's acreage. Do not use in sandy soils where groundwater levels are less than 10 feet deep. Use spot treatment on slopes where rapid runoff can occur. Do not use where surface runoff may flow to adjacent broadleaf crop areas. Apply to forage grasses only. Do not rotate treated pastures to other crops for at least 2 years after application. Do not treat pastures having desirable legumes. Do not move livestock from a treated area to a broadleaf crop area without first grazing 7 days on untreated grass pasture.
Roundup (glyphosate)	2% solution (spot treatment)	Controls a variety of herbaceous and woody brush species such as multiflora rose, brambles, poison ivy, quackgrass. Spray foliage of target vegetation completely and uniformly, but not to point of runoff. Avoid contact with desirable nontarget vegetation. Consult label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Allow 14 days after application before grazing or harvesting forage.

Table 5. — Weed Control in Forages

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
PURE LEGUME FORAGES					
Seedling year					
Balan 1.5EC	Alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	Preplant incorporated	3 to 4 qt	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on soils high in organic matter.
Eptam 7E or Genep 7E	Alfalfa, birdsfoot trefoil, lespedeza, clovers	Preplant incorporated	3½ to 4½ pt	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on white Dutch clover.
Butyrac 200 or Butoxone	Alfalfa, birdsfoot trefoil, ladino clover, red clover, alsike clover, white clover	Postemergence	1 to 3 qt (amine) 3 to 4 pt (ester)	Use amine or ester formulation when weeds are less than 3 inches high, or less than 3 inches across if rosettes. Use higher rates for seedling smartweed or curly dock. Do not use on sweet clover.	Do not harvest or graze for 60 days following treatment.
Dinoseb (amine)	Alfalfa, birdsfoot trefoil, red clover, ladino clover, sweet clover	Postemergence	1½ to 2 qt	Apply when legume has two or more leaves and weeds are small. Cool (below 70°F) or drought conditions may reduce control.	Do not harvest or graze for 6 weeks following application.
Furloe 4EC	Alfalfa only Certain clovers and birdsfoot trefoil	Postemergence	1 to 3 qt 1 to 2 qt	Apply after the 4-leaf stage in alfalfa. Used mainly for chickweed control.	Do not harvest or graze for 40 days.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Postemergence	1 to 3 lb	In fall-seeded legumes, apply after legumes have reached trifoliate stage. In spring-seeded legumes, apply next fall.	Do not graze or harvest for 120 days following application.
Established stands					
Butyrac 200 or Butoxone	Alfalfa only	Growing	1 to 3 qt (amine) 3 to 4 pt (ester)	Use amine or ester formulation. Spray when weeds are less than 3 inches high, or less than 3 inches wide if rosettes. Fall treatment of fall-emerged weeds may be better than spring treatment. Do not apply to sweet clover.	Do not harvest or graze for 30 days following application.
Furloe 4EC	Alfalfa only Certain clovers and birdsfoot trefoil	Growing or dormant	1 to 3 qt 1 to 2 qt	Apply when moisture is sufficient to move herbicide into root zone. Used mainly for chickweed control.	Do not harvest or graze for 40 days following application.
Kerb 50W	Alfalfa only	Growing or dormant	1 to 3 lb	Apply in fall after last cutting when weather and soil temperatures are cool.	Do not harvest or graze for 120 days.
Dinoseb (amine)	Alfalfa, birdsfoot trefoil, ladino clover, red clover, sweet clover only	Growing or dormant	1 to 4 qt	Use lower rates for chickweed seedlings in growing legumes. Where weeds become well established, use higher rates but delay application until legume is dormant.	Do not graze or feed treated forage within 6 weeks after spraying.
Princep 80W	Alfalfa only	Growing or dormant	1 to 1½ lb	Apply once per year in the fall after last cutting but before ground freezes permanently.	Do not use on sandy soils. Allow 30 days between application and grazing livestock; 60 days between application and cutting for hay.

Table 5. — Weed Control in Forages (continued)

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
Sencor or Lexone 4L 75 DF 50 WP	Alfalfa only	Dormant	¾ to 2 pt (4L) ½ to 1⅓ lb (75 DF) ¾ to 2 lb (50 WP)	Apply once in the fall or spring before new growth starts. Rate based upon soil type and organic matter content.	Do not use on sandy soils or soils with pH greater than 7.5. Do not graze or harvest for 28 days.
Sinbar 80W	Alfalfa only	Dormant	½ to 1½ lb	Apply once in the fall or spring before new growth starts. Use lower rates for coarser soils.	Do not use on sandy soils with less than 1% organic matter. Do not plant any crop for 2 years.
Velpar L	Alfalfa only	Dormant	1 to 3 qt	Apply in the fall or spring before new growth exceeds 2 inches in height. Can also be applied to stubble after hay crop removal but before regrowth exceeds 2 inches.	Do not plant any crop except corn within 2 years of treatment. Corn may be planted 12 months after treatment, provided deep tillage is used. Do not graze or harvest for 30 days.
Paraquat CL Gramoxone	Alfalfa only	Dormant	2 to 3 pt	Apply after last fall cutting or before spring growth is 1 inch tall. Weeds should be succulent and growing at the time of application. Weeds germinating after treatment will not be controlled.	A restricted use herbicide. Do not apply if fall regrowth following the last fall cutting is more than 6 inches tall. Do not harvest or graze for 60 days.
Roundup	Alfalfa or clover	Growing	2% solution (spot treatment)	Apply to actively growing, susceptible weeds. Avoid contact with desirable, nontarget vegetation as damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Do not graze or harvest for 14 days.
MIXED GRASS-LEGUME FORAGES					
Established stands					
Sencor or Lexone 4L 75 DF 50 WP	Alfalfa-grass mixtures	Dormant	¾ to 1½ pt (4L) ½ to 1 lb (75 DF) ¾ to 1½ lb (50 WP)	Apply once in the fall or spring before new growth starts. Rate based on soil type and organic matter content. Higher rates may injure grass component.	Do not use on sandy soils or soils with pH greater than 7.5. Do not graze or harvest for 28 days.
Roundup	Alfalfa or clover-grass mixture	Growing	2% solution (spot treatment)	Apply to actively growing, susceptible weeds. Avoid contact with desirable, nontarget vegetation as damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Do not graze or harvest for 14 days.

Table 6. — Effectiveness of Herbicides on Weeds in Legume and Legume-Grass[a] Forages

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, and P = poor.

	Balan	Genep Eptam	Butyrac, Butoxone	Dinoseb	Furloe	Kerb	Paraquat, Gramoxone	Princep	Sencor, Lexone[a]	Sinbar	Velpar	Roundup[a]
Barnyardgrass	G	G	P	P	P	F	F	F	F	F	G	E
Chickweed, common	P	P	P	G	G	F	G	G	G	G	G	E
Crabgrass	G	G	P	P	P	F	F	F	F	G	G	E
Dandelion	P	P	F	P	P	P	F	F	G	P	G	G
Dock, curly	P	P	P	P	P	P	F	P	P	P	P	G
Downy brome	G	G	P	P	G	G	G	G	G	G	F	G
Fall panicum	G	G	P	P	P	P	F	F	F	P	P	E
Foxtails	G	G	P	P	P	F	F	F	F	G	G	E
Lambsquarters	G	G	F	G	P	P	F	G	G	G	G	E
Mustard, wild	P	P	E	G	P	P	G	F	G	G	G	E
Nightshade[b]	P	F	F	F	F	P	F	P	G	P	P	E
Orchardgrass	P	P	P	P	P	F	F	F	F	F	G	F
Pigweed	G	G	F	G	P	P	F	G	G	F	G	E
Quackgrass	P	F	P	P	P	P	P	F	F	F	F	G
Ragweed, common	P	P	G	G	P	P	F	G	G	F	F	E
Shepherdspurse	P	P	G	G	P	P	G	G	G	G	G	E
Smartweed	P	P	P	G	F	P	F	F	F	F	F	E
Yellow nutsedge	P	F	P	P	P	P	P	P	F	P	P	F

[a] Sencor, Lexone, and Roundup are labelled for use in mixed legume-grass forages. No other herbicides are cleared for this use.
[b] Control of different species may vary.

Useful Facts and Figures

To convert column 1 into column 2, multiply by	Column 1	Column 2	To convert column 2 into column 1, multiply by
	Length		
.621	kilometer, km	mile, mi.	1.609
1.094	meter, m	yard, yd.	.914
.394	centimeter, cm	inch, in.	2.54
16.5	rod, rd.	feet, ft.	.061
	Area		
.386	kilometer², km²	mile², mi.²	2.59
247.1	kilometer², km²	acre, acre	.004
2.471	hectare, ha	acre, acre	.405
	Volume		
.028	liter	bushel, bu.	35.24
1.057	liter	quart (liquid), qt.	.946
.333	teaspoon, tsp.	tablespoon, tbsp.	3
.5	fluid ounce	tablespoon, tbsp.	2
.125	fluid ounce	cup	8
29.57	fluid ounce	milliliter, ml	.034
2	pint	cup	.5
16	pint	fluid ounce	.063
	Mass		
1.102	ton (metric)	ton (English)	.907
2.205	kilogram, kg	pound, lb.	.454
.035	gram, g	ounce (avdp.), oz.	28.35
	Yield		
.446	ton (metric) hectare	ton (English)/acre	2.24
.891	kg/ha	lb./acre	1.12
.891	quintal/hectare	hundredweight/acre	1.12
.016	kg/ha-corn, sorghum, rye	bu./A.	62.723
.015	kg/ha-soybean, wheat	bu./A.	67.249
	Temperature		
(9/5·C)+32	Celsius	Fahrenheit	5/9(F−32)

Plant Nutrition Conversion

P(phosphorus) $\times$ 2.29 = P_2O_5 — $P_2O_5 \times .44 = P$

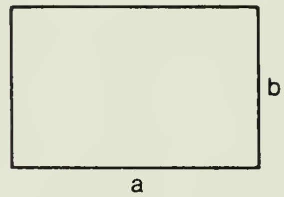
K(potassium) $\times$ 1.2 = K_2O — $K_2O \times .83 = K$

ppm x 2 = lb./A. (assumes that an acre plow depth of 6⅔ inches weighs 2 million pounds)

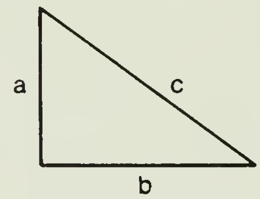
Useful Equations

$$\text{Speed (mph)} = \frac{\text{distance (ft.)} \times 60}{\text{time (seconds)} \times 88}$$

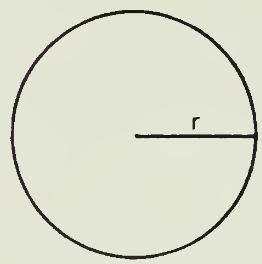
1 mph = 88′/min.



Area = a × b



Area = ½ (a × b)



Area = πr^2
π = 3.1416

$$\text{lb./100 ft.}^2 = \frac{\text{lb./acre}}{435.6}$$

$$\text{Example: 10 tons/acre} = \frac{20{,}000\text{ lb.}}{435.6} = 46\text{ lb./100 ft.}^2$$

$$\text{oz./100 ft.}^2 = \frac{\text{lb./acre}}{435.6} \times 16$$

$$\text{Example: 100 lb./acre} = \frac{100}{435.6} \times 16 = 4\text{ oz./100 ft.}^2$$

$$\text{tsp./100 ft.}^2 = \frac{\text{gal./acre}}{435.6} \times 192$$

$$\text{Example: 1 gal./acre} = \frac{1}{435.6} \times 192 = .44\text{ tsp./100 ft.}^2$$

Water weight = 8.345 lb./gal.

Acre-inch water = 27,150 gal.